CLIMATE TECH

EVALUATION OF TECHNOLOGY IN CLIMATE ACTION WITH A LENS OF MATERIALITY AND DATA JUSTICE

MASTER'S THESIS
AALTO MEDIA LAB

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Master of Arts thesis abstract

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Abstract

This thesis examines the ongoing climate crisis, and the role technology plays in approaching the crisis. It first establishes a clear definition of the climate crisis and related terminology, provides evidence, highlights how grave the situation is, and further repercussions if no significant action is taken. Next, the thesis evaluates existing climate action work and its high reliance on technology as the main tool in the process.

Technology and its dependence have been growing each year exponentially. The thesis points out some significant problems and challenges with such reliance on technology- its material and emission cost, lack of equal access, extractive business models, and more such issues. The thesis offers ways to account for these problems through alternative solutions, institutional shifts, and guidelines and insights for technology usage in climate action projects.

The research involves understanding existing literature and following closely ongoing work and projects. And practice-led research through the author's work and projects with a climate action organisation called Dark Matter Laboratories. The thesis zooms into two main climate tech methods- monitoring and financing. Establishing both methods, reason of choice, problems, gaps, and possible solutions for improving them.

The thesis focuses on two of the author's project work in the EU- Nature-based Solutions(NbS) and Retrofit. NbS focuses on maintaining urban city forests and the investment and monitoring systems needed to sustain the infrastructure. Retrofit project analyses the need for continuous maintenance of homes and residential areas to curb their high emissions and create a more viable living space. Both projects are centred around using technology and data; the thesis analyses how these projects tackle technology's embedded challenges. Some of the alternate solutions are- forming a material registry, open shared standards, transparency, and community building.

The projects are still in progress and evolving gradually. In conclusion, the thesis offers guidelines that can be used by anyone working on climate action through technology. The guidelines give a checklist and evaluation framework for before, during, and after states of a project to clearly understand technology's role and address possible issues. The guidelines mainly focus on using low-tech solutions, forming data trusts, embedding indigenous protocols in technology, and the need for an institutional and societal shift concerning technology.

Keywords: climate crisis, climate action, climate tech, materiality, data justice, nature based solutions, retrofit

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1.INTRODUCTION

1.1 PROBLEM BACKGROUND

1.1.1 Climate crisis in the anthropocene

The term ‘climate crisis’ has been growing prominent in the last few years but originated already in the 1980s[1]. The goal is to bring more serious attention to the already known term- climate change. The term climate crisis packs a lot into it, one of the main points being the large-scale shift in weather patterns and global temperatures rising. This shift has lead to and is interlinked with numerous geophysical events taking place-

1. Melting of glaciers
2. Rising sea levels
3. Food and water insecurity
4. Natural disasters

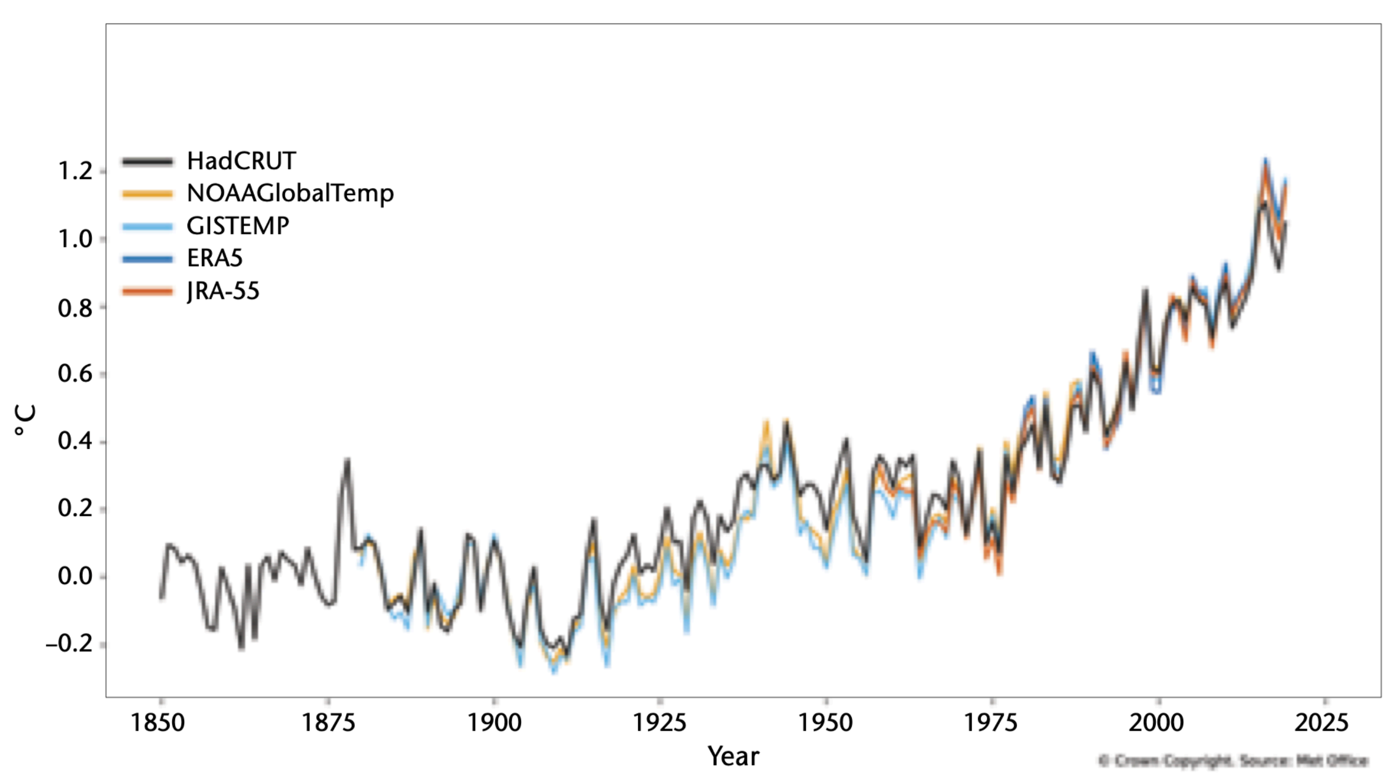


Figure 1 - Global annual mean temperature difference from pre- industrial conditions (1850–1900). The two reanalyses (ERA5 and JRA-55) are aligned with the in situ datasets (HadCRUT, NOAAGlobalTemp and GISTEMP) over the period 1981–2010. [2]

Details and evidence of rise of temperature

The global temperatures have been constantly rising with 2019 seeing some of the highest levels of increase since 1850–1900 baseline[2].

Both figure 1 and 2 show steep rise in global temperatures from 1980 and how it is affecting the natural systems like melting of ice and rising sea levels.

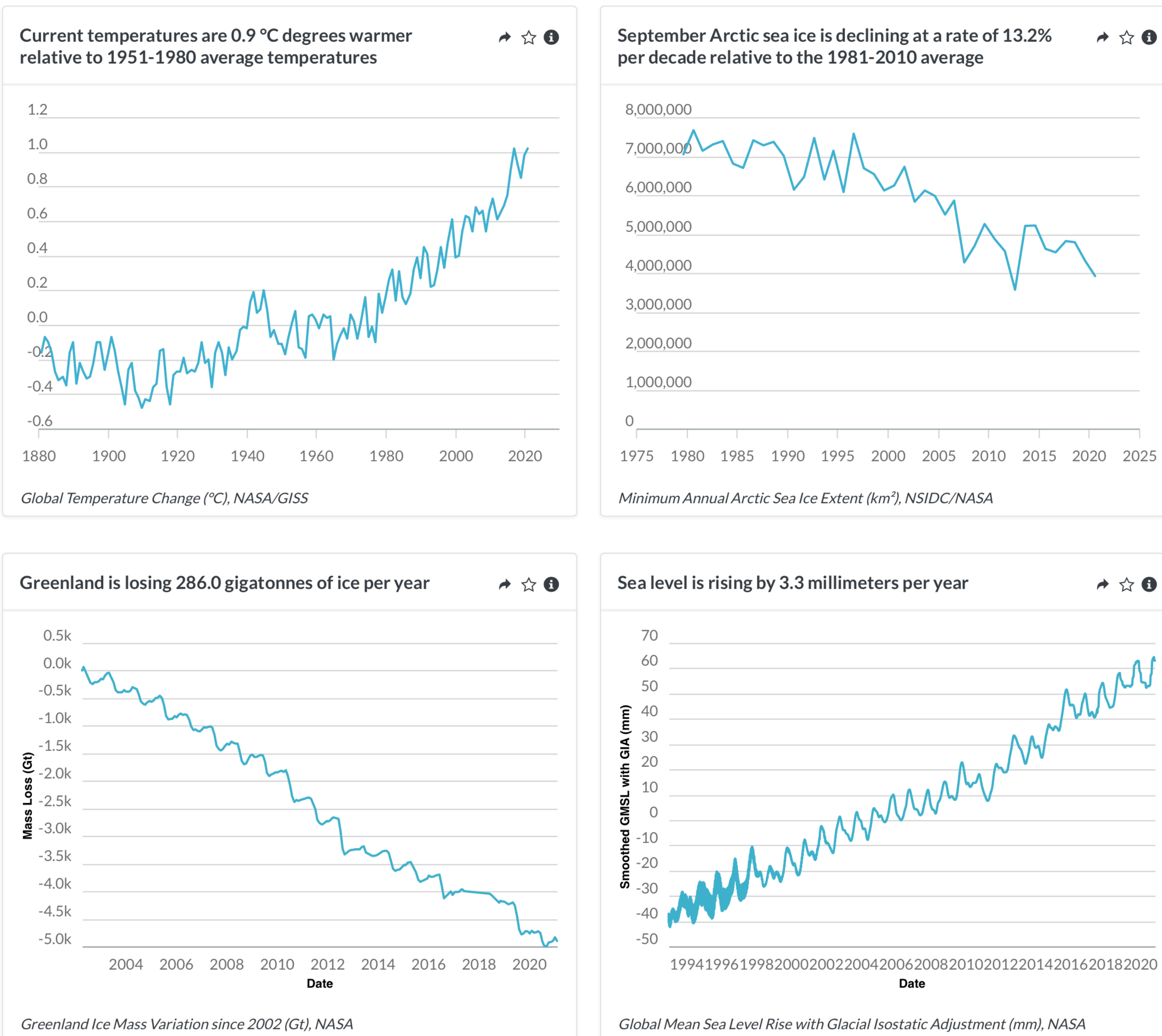


Figure 2 - Climate change trends, taken from Resource Watch dashboard[3]

What has lead to the crisis?

It is evident from the figure 1 that human industrialisation activity which has been on the rise, has contributed the most to the crisis. Not only that, most human systems and infrastructures of energy, food, farming, supply chain, and construction all have accelerated the crisis. Clearing of natural lands like forests, mass production of resources and land, and degrading soil with chemicals all have accelerated this crisis further.

Systems created by humans which control the wealth in the hands of the 1%, and capitalism's constant growth-seeking has further accelerated the climate crisis. According to Oxfam, "carbon emissions of the richest 1 percent more than double the emissions of the poorest half of humanity."[4] Hence the climate crisis is a systematic problem perpetuated by global institutions.

Individual privileged behaviours in the Global North and mass consumerism also further contribute to the crisis.

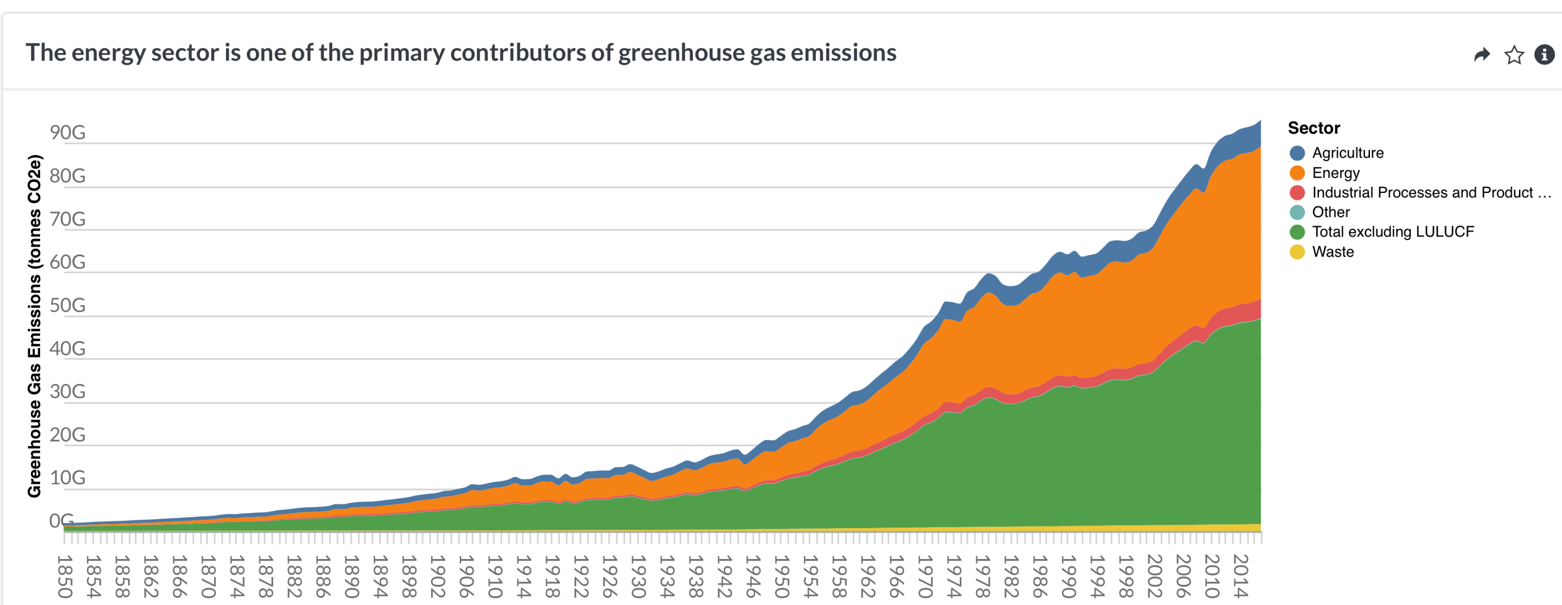


Figure 3 - Climate change contributors by sector, taken from Resource Watch dashboard[3]

What could happen if the crisis is not dealt with?

According to the WMO report[2], without taking any action, the current trend will lead to a 3-5 degrees of more temperature rise by the end of the century and a lot further drastic changes.

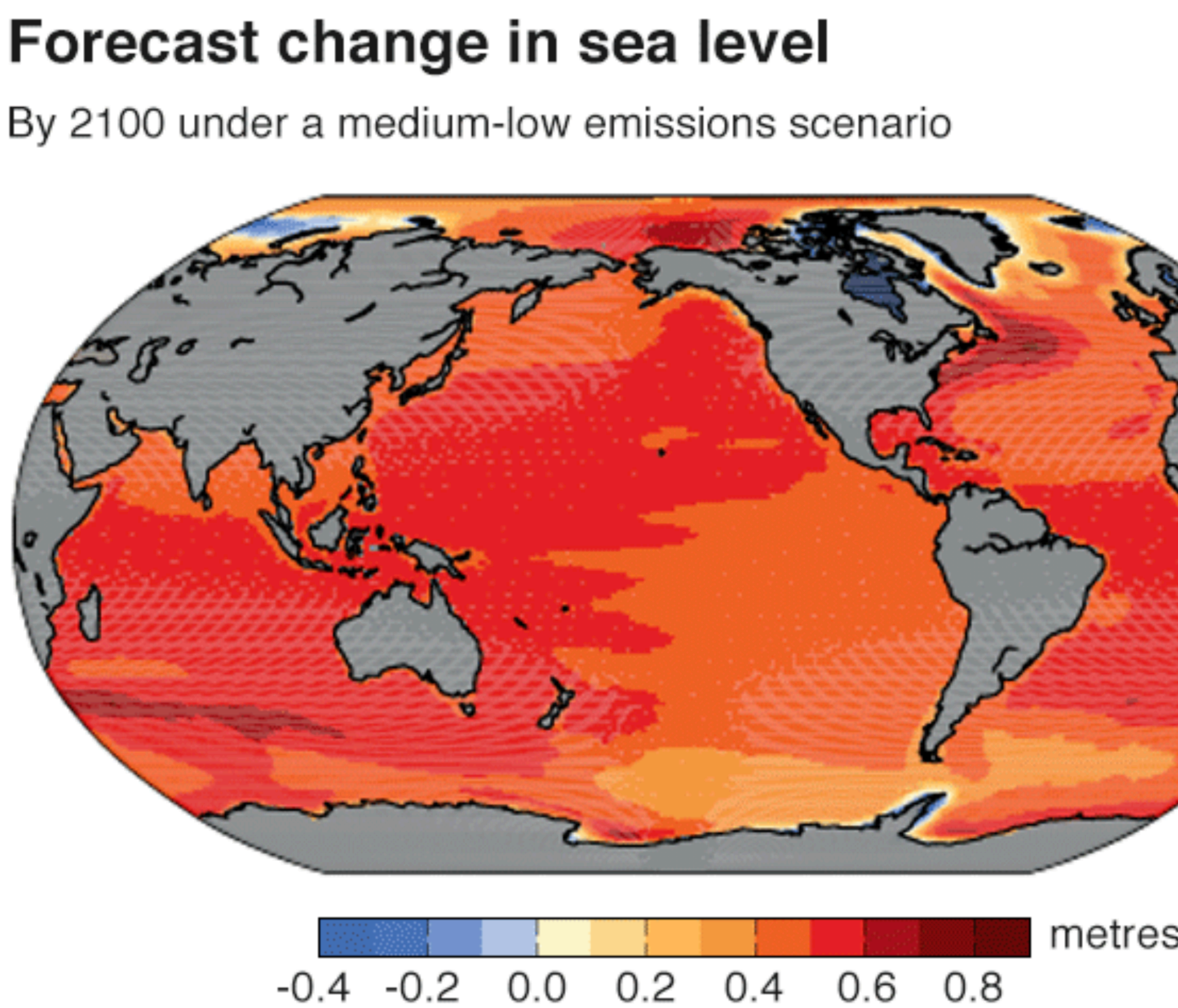


Figure 4 - 2100 emissions and temperature scenario taken from IPCC

Rising temperature and sea levels will make most cities inhabitable. Food shortages, wildfires, more natural disasters, and more animal species being extinct, and eventually leading to mass extinction of human beings.

1.1.2 Climate action

Even though it is pretty clear how important it is to take action to prevent the crisis from worsening, historically, people have been bad at this, as there have been indicators of the climate crisis for a long time now. Still, these indicators have not been met with the needed action, and the data in the previous section supports that. There has been a lot of lobbying and lax regulation by big oil and mining companies.

The large variety of research and project work that has been continuously going on cannot be discounted. Work in understanding the crisis in more detail, monitoring the environment in more detail, making significant changes in energy and financial sectors, and even working on dealing with a possible collapse scenario.

What actions are being taken at large scale

1. Shift towards renewable energy
2. Afforestation and forest conservation projects
3. Activism and awareness
4. Paris Agreement
5. Net-zero cities
6. DIY and community initiatives

It is important to note each action comes with very different effects and needs to be executed in an informed way. Some activities end up doing more damage than alleviating the situation. Most of these actions are also non-uniform and implemented differently by different countries.

Who is taking action?

1. UN and public bodies
2. Country and local governments: Different countries are working towards climate action in different ways. Most countries who signed the Paris agreement have set common goals, but the method and time of execution vary.
3. Think tanks, scientists, and SMEs: Various think tanks worldwide are researching different aspects of the crisis and how to make changes in society.
4. NGOs: Many NGOs are doing work on the ground to take needed action.
5. People: Changed in lifestyle, everyday choices, and activism.
6. Corporates and foundations: Corporate social responsibility and big foundations are running grants and funding programs.

Figure 5 - UN sustainable development goals

Another very significant climate action work is the Paris Agreement-

“The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels.”[5]

Complex entanglements

As mentioned before, the climate crisis results from many entanglements together encompassing social systems, wealth distribution, racism, patriarchy, energy, economic systems, education, and more. Hence understanding and making a change to such a complex system is very hard.

1.1.3 Climate action tech

Technology in different forms has been an integral part of climate action. Technology is a broad term entailing measuring instruments, research and lab tools, environment sensors, databases, etc. But as technology has been evolving at a rapid stage with innovations every day, it is enabling new kinds of functions. As stated before, the climate crisis is quite a complex problem to understand; fast computing allows us to analyse and understand high-dimensional data in a short time. Novel and still in progress tech like Artificial Intelligence(AI), Quantum Computing, cryptocurrencies are being applied to climate action projects on a rapid scale. But technology comes with a cost, which this thesis aims to evaluate.

Most common tech applications for climate action

- **Sensors to measure and understand**: Various sensing techniques from satellite imagery, LiDAR, IoT(Internet of things) based sensors, and citizen sensing used to calculate any given natural or human-created system.
- **Artificial Intelligence(AI)**: AI-based modelling to fill gaps and make predictions. Data recorded from sensing techniques being fed to Artificial Intelligence-based models to create synthetic data to fill in where data does not exist and also be able to make future predictions using historical data and correlations.
- **Financial systems for investment**: Alternate financial redistributions and business models enabled by tech to challenge existing centralised wealth distribution problems.
- **Trusted supply chains**: Combining sensing with open databases to give a transparent view of material supply chains.
- **Information propagation, involvement, decision making**: Easy ways to reach out and connect with a high number of people, share information, perform consensus, and voting.
- **Visible dashboards**: Being able to visualise and transparently show all data being recorded with easy to understand insights and multiple views
- **More in research**: And a lot of other projects in progress.

Projects vary in scale and are being conducted by big companies, governments, small startups, think tanks, research agencies, and NGOs. Another trend among such climate action tech is that it is open source in most cases. Two such examples being-

1. **Projects by Google Sustainability**[6]: A suite of tools created for climate action by private profit-driven Google/Alphabet. Most of these tools are created and released as open-source to be used by anyone. Tools include using LiDAR and AI for calculation potential of solar energy for a given building, analysing global fishing and forest patterns, a database to show worldwide energy and power distribution, and more.
2. **Open Sustainable Technology**[7]: “A curated list of open technology projects to sustain a stable climate, energy supply, and vital natural resources.”[7] An

excellent and handy list of going open source projects, applications, and tools can be easily integrated and used in a given climate action project. Categories include- renewable energy, energy storage and grid, emissions, ecological footprint, biosphere, natural resources, agriculture, and investment.

Figure 6 - Screenshot Project Sunroof by Google[6]

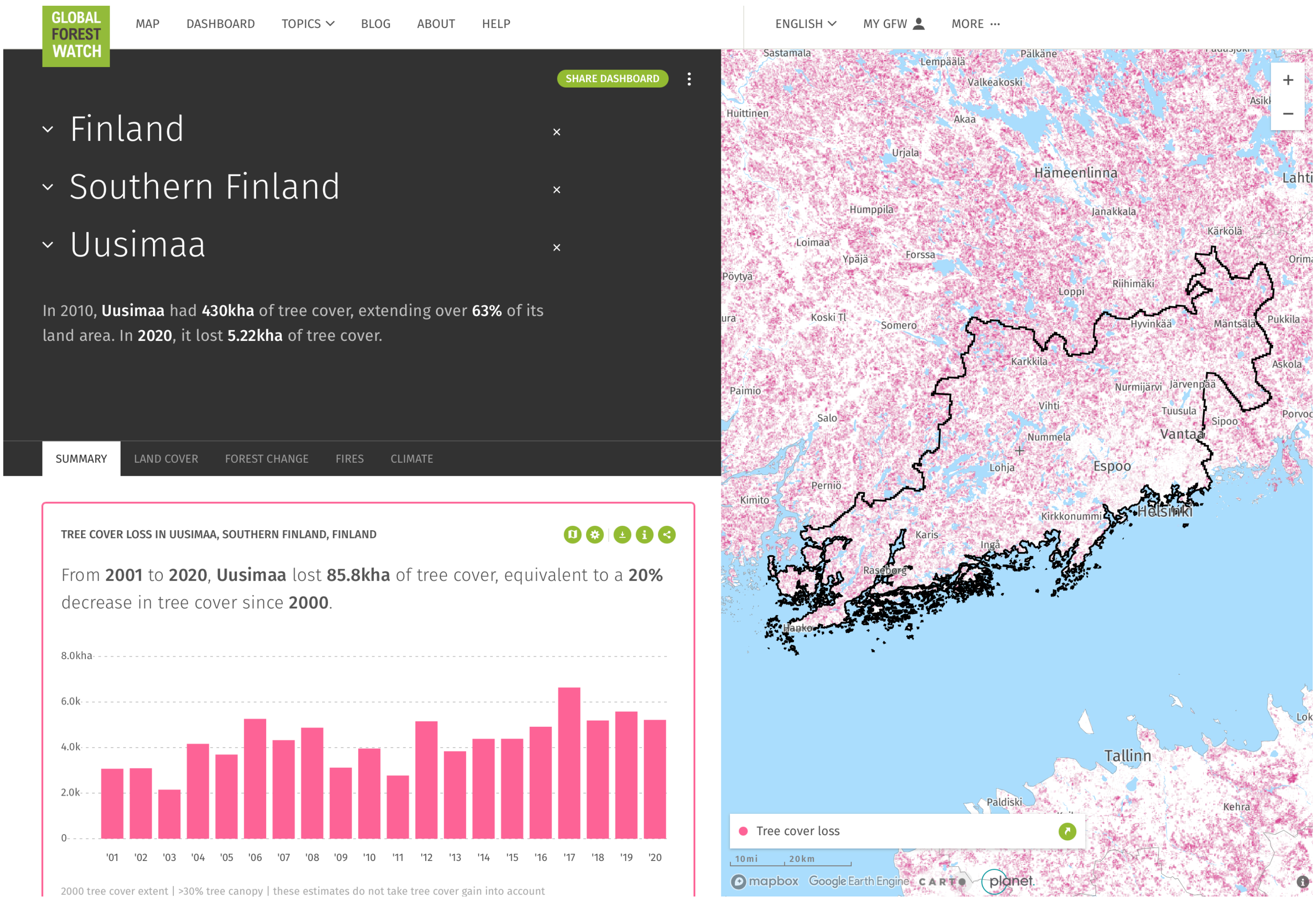


Figure 7 - Screenshot of Global Forest Watch by Google[6]

1.2 GAPS IN THEORY AND PRACTICE

Climate tech efforts are quite scattered with less amount of shared learning. Technology's carbon and material issues are discussed in detail later in this section. And questions concerning the ownership of such technology and digital infrastructures are also quite open, as the price of such tech becomes quite expensive. Local city councils do not have the full capacity to own and maintain such services in most cases. There is a danger of manipulating such data and services and capitalising from it instead of working towards climate targets. There is a significant need to research and understand the long-term impacts of such technology and form viable models, audit mechanisms, and legal systems around it to make sure the tools guide us in the right direction.

1.2.1 Tech's extractive models

Prevalent advertisement-based business models employed by Big Tech companies based on understanding the person's interests are based on their usage, selling that data to ad providers with hopes and promises of increasing their brand's relevance and sales. These hopes are mostly not met, but Big Tech companies keep getting bigger. One of the main dangers of these models lies in that they can also influence a person's behaviour. There is evidence of using such techniques to influence US elections of Donald Trump winning and even behind the campaign, which led to Brexit in the UK. Also, these platforms have been used to promote riots and violence. Cyberbullying is a big problem. Hence such embedded business models can lead to more damage by climate tech than aiding the issues at hand.

At the same time, these platforms are also being used for activism and assembling. But such activism is often met with bans and resistance from the companies. Big Tech needs proper regulation and a deeper understanding of such tech and ramifications.

1.2.2 Tech materiality

Technology is often considered the clean saviour to society, the centre of all human progress. Tech billionaires are lauded as heroes, tech-solutionism as means to it all, and tech fetishism shown by consumers. But often ignored is the material cost of technology, the tech materiality. The hardware parts and chips needed come from mining in conflict areas, leaving a profound impact on the earth's resources. "Data centres account for 200 TWh yr–1, or around 1% of total global electricity demand. While their energy usage has been stable in recent years as efficiencies increase, it may grow to between 15–30% of electricity consumption in some countries by 2030."[8] The cost of running these applications relies on giant data centres and energy infrastructures, termed lightly as 'the cloud', which is nothing but large data centres running on heavy energy, usually coal-powered.

The reliance on cloud solutions and phones/devices has immensely increased with even more growing dependence on digital services during lockdowns periods of COVID 19. High-speed 5G infrastructures are on the rise and enable much faster speeds and usage of technology. Novel technologies like AI and Quantum Computing need a lot more processing power, leading to more emissions peruse. Bitcoin and other cryptocurrencies have also been in the limelight in the last few years. And Bitcoin's carbon emissions are more considerable than some countries's total emissions combined[9]. Still, tech is being cited as one of the primary tools for the climate crisis.

Cloud has its brand oriented to hide the invisible structure behind all the applications. And Big Tech companies are competing with each other while also being immense gatekeepers to small-scale providers. In the end, it also connects back to the established culture of mass consumerism. The consumption levels need to be challenged and addressed first. Design is being used to deceive us and make us addicted to these services and use them as much as possible. Companies also employ planned obsolescence to increase revenue and without giving proper means of repair. How such issues are addressed is commonly approached by finding solutions to the immediate problems and not challenging the source of the problem itself. This concept can be coined as Western Melancholy[10].

There is research and reliance on clean energy-based data centres. Google has committed to being carbon-free by 2030[11], but what do these commitments mean? There is a lot of greenwashing and difficulty in validating reality. Most of the work is solar-powered data centres and novel techniques like shifting data centres to cold countries like the Nordics for easier cooling. Still, this effort needs to be consolidated together. The assumption that renewable energy or clean energy is free needs to be checked. There is a vast infrastructure need for renewable energy and challenges of recycling solar panels, for example. Hence there is a need to make a full accounting of such systems.

Figure 8 - Women take devices apart in a warehouse in Guiyu, taken by Kai Löffelbein part of collection Ctrl-X, A topography of ewaste[12]

“DOWNLOADING 100 MEGABYTES, 10 TIMES PER MONTH, RESULTS IN 1.219 KILOS OF CO2 EMITTED PER MONTH.”[13]

1.2.3 Lack of common standards, licensing and regulation

Many works are scattered, even though they are following open data standards, but still, there is a lack of fully agreed and trusted standards. There isn’t a shared agency to use and evolve those standards. Though there is growing work by many city councils and countries to create open data portals and even create data models and protocols, there is still a lack of mass adoption and agreement. Having shared data standards will lead to shared understanding and collaborative efforts worldwide and make an entry for a new city more straightforward.

Many open licenses are available from Creative Commons, the UK government’s Open Government License, and various other popular ones known in coding communities[14]. Still, there is a lack of knowledge of their details, usage, and dedicated licensing choices for climate action. Open source code still requires a certain amount of expertise and capacity to use and implement.

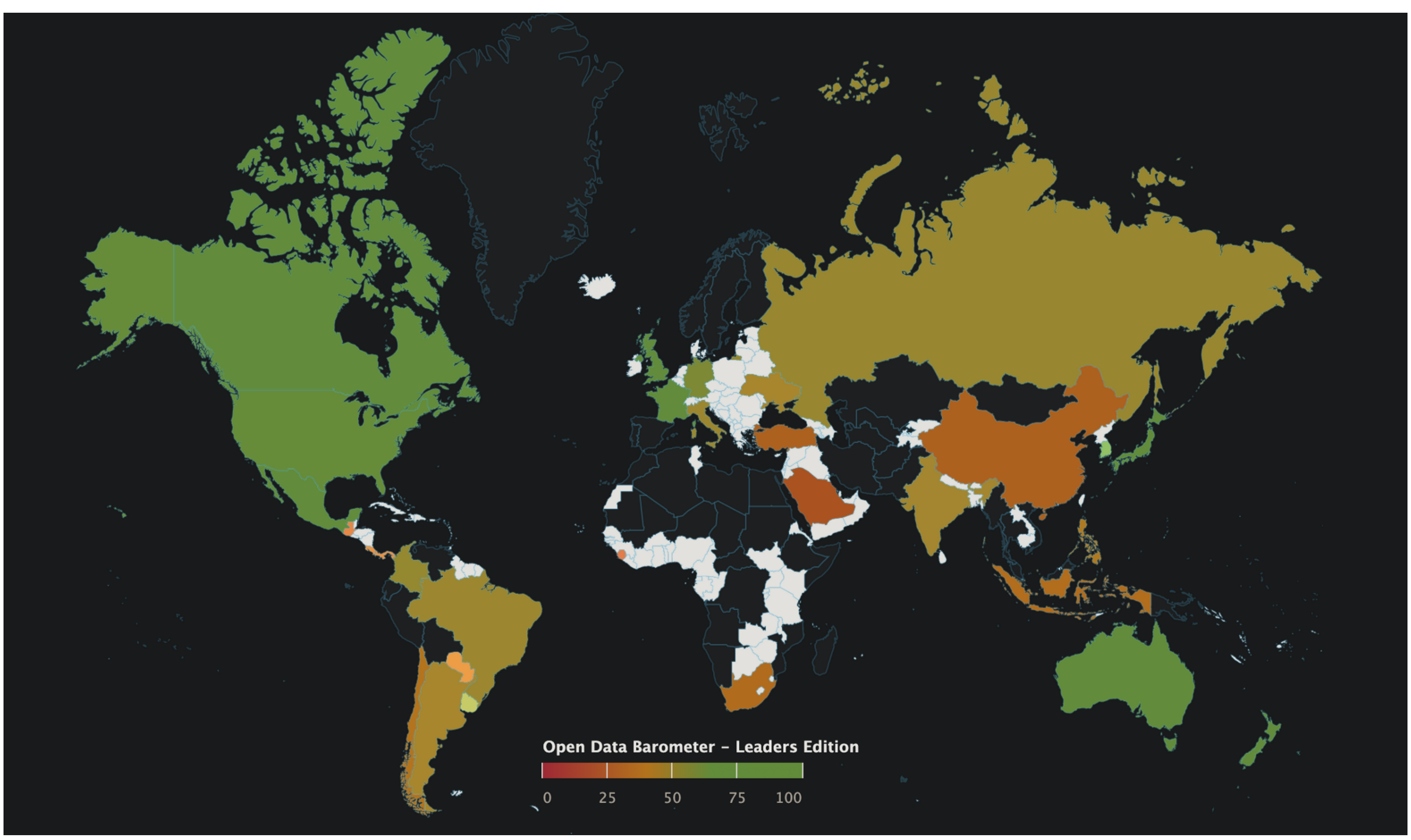


Figure 9 - Countries ranked by quality of their open data, created by Open Data Barometer[15]

Regulation and legal frameworks have failed to keep up with the changing shape of technologies and their new kind of relationships.

1.2.4 Lack of access to the Global South

There still isn't full accessibility to technology in all countries. It requires high capital investment to purchase and maintain. Even with open source solutions, high expertise is needed to use and deploy the solutions. Affordable and clean energy and internet infrastructures are required as well.

1.2.5 More and more increasing unchecked dependence on Big Tech companies

Big Tech companies such as Microsoft, Google, Amazon, Alibaba, Facebook have a monopoly and control of building blocks of climate tech like data centres, cloud operating functions, AI modules, open-source projects, and more. In many cases, there is dependence on their products for producing high-scale applications needed for climate tech. This dependence can be problematic as climate action gets entangled by the intentions of these companies.

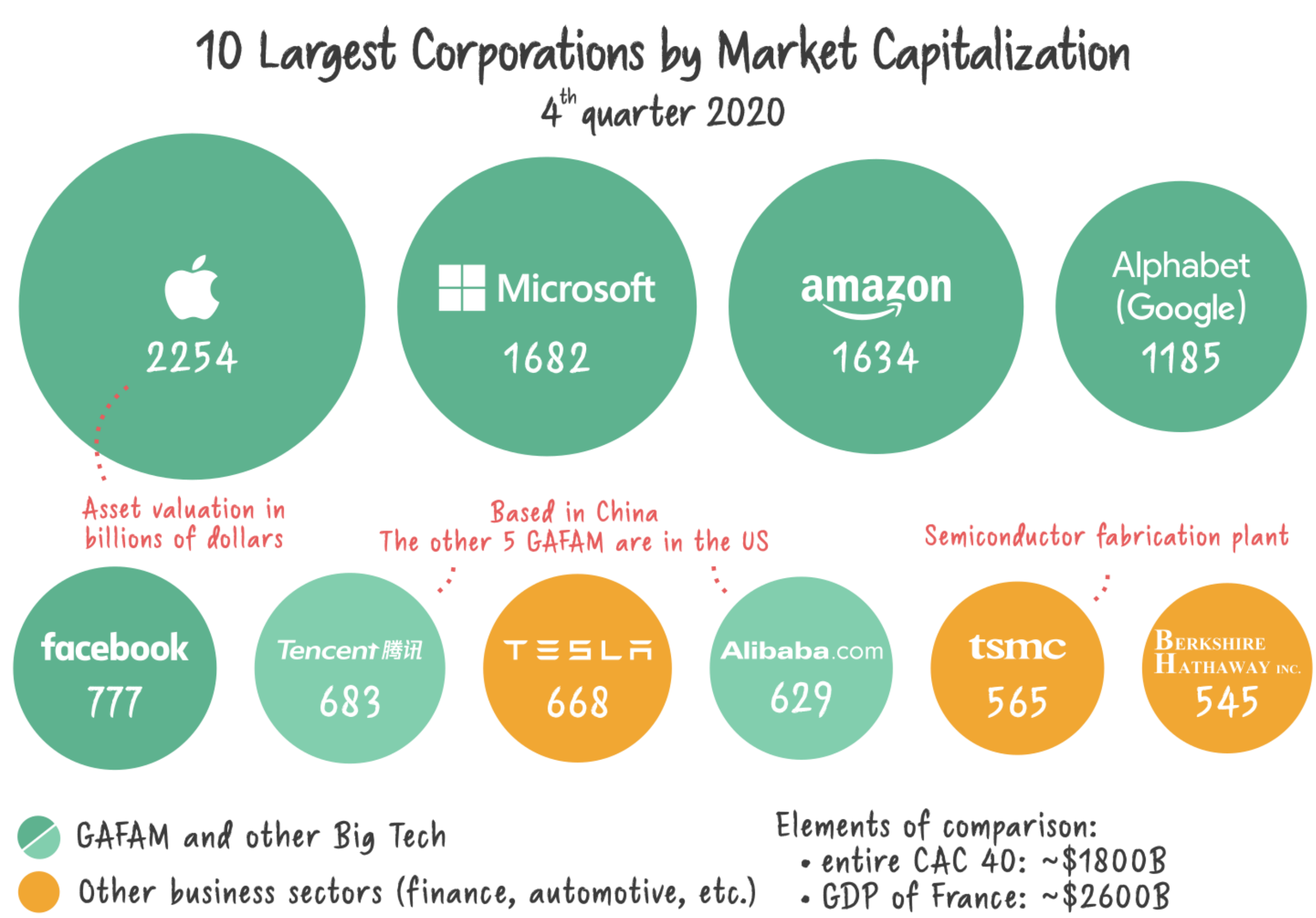


Figure 10 - 10 largest corporation by market capitalisation[16]

2020 Cloud League Table

Cloud	Rating	Sustainable Servers?
Google	**A-**	**100% with offsets today, with commitment to 'real time matching' (i.e. no carbon release)**
Azure	**A-**	**100% with offsets and energy certificates today, with commitment to be carbon negative by 2030**
AWS	**C-**	**100% with offsets only in four public regions today, elsewhere unknown with estimates in the less than 30-50% range. New commitment to carbon neutrality by 2030 and carbon zero (no carbon release) by 2040. The rating here would be higher but for the continuing lack of transparency on energy usage.**
Oracle	**C-**	**100% with offsets in a few regions <30% overall**
IBM	**C-**	**~50% overall**
Alibaba	**D-**	**Unknown but China a major market, and not known what energy is purchased**

Figure 11 - Big Tech cloud sustainability ratings taken from The State Of Data Centre Energy Use[17]

1.3 HYPOTHESIS

There needs to be a fundamental change in tech systems to make it the needed climate action tool.

By institutional-level changes in ownership models and precise regulation, climate tech methods could be made more transparent.

Creating a material registry based on open standards could make climate tech transparently report its material and operation costs with all protocols and practices informed and guided by design justice principles[18] and creating data trusts[19].

1.4 RESEARCH QUESTIONS

WHAT IS THE IMPORTANCE AND ROLE OF TECHNOLOGY IN CLIMATE ACTION?

HOW CAN TECH MATERIALITY AND TECH'S EXTRACTIVE POSSIBILITIES BE ACCOUNTED FOR WHEN USING TECHNOLOGY FOR CLIMATE ACTION?

1.5 METHODOLOGY

1.5.1 Studying and analysing existing projects in climate tech domain

There has been in-depth and critical analysis of existing literature, academic papers, ongoing project work around the climate crisis, climate action projects, and climate action technology.

1.5.2 Developing frame of 2 climate tech methods

The author has worked in few cities across the EU with a climate action organisation to explore the climate crisis and how technology can aid a given problem at hand. The work includes- conducting interviews and workshops with city councils, creating and testing prototypes, producing blogs & reports, and working with various stakeholders and ongoing local projects. A focus on two specific climate action methods is chosen from this work, emerging from the projects and selected for the scope of this thesis.

1.6 THESIS STRUCTURE AND NARRATIVE

The first section establishes the thesis context by introducing the climate crisis and why it is so important. Then the thesis opens up details about climate action and the role of technology in it. There is a focus on various gaps and problems as well. This section is followed by the hypothesis and research questions, and methodology.

Next, the thesis introduces two climate tech methods- monitoring and financing. And an explanation of the reason behind the choice of two methods, how they were developed, their problems, the literature around them, and gaps in the literature.

Then the thesis goes over details of two projects in which the author was involved with a focus on the climate action methods mentioned and how alternative solutions were used to overcome the problems and gaps. Finally, the last section gives guidelines for climate action projects, covering the author's insights and lessons from the projects.

2. TWO CLIMATE TECH METHODS IN FOCUS

As highlighted before, the climate crisis and its understanding are very complex. For the scope of this thesis, there is a focus on two climate tech methods. These methods are chosen due to the author's research and project work, categorising two important domains into two- the first being **monitoring** and the second being **financing**. This chapter opens up these two methods further.

2.1 INTRODUCTION OF THE TWO CLIMATE TECH METHODS

Monitoring: the activity of sense-making of our physical world which includes human activities, biodiversity, and all processes to understand micro and macro details and make connections and accurate predictions and forecasts. Monitoring has been an integral part of science since the very early days, but monitoring sensors, the ability to record and retrieve data, and sense-making mechanisms have been advancing rapidly. It is quite an essential process as it is the entryway to first understanding the climate crisis, measuring baseline numbers, and monitoring any positive or negative changes. Thus there is also a minimal margin for error as if the monitoring is giving false numbers; the whole project becomes very misguided.

Financing: accounting of value and transactions between entities. Financing and allocating funds is how our built world and economic value system work. For any project or initiative to get mass adoption, it needs to finance itself in some way. There is a need for continuous funds through trusted and stable financial mechanisms and not one-time charity payments to make the required long-term changes for climate action. Financing systems also work as a medium to motivate human behaviour. Lastly, there is a need for financial systems to regulate unfair wealth distribution and help underprivileged people and the Global South. Financial systems in the form of taxes can also start the needed institutional shift from the big companies contributing to the crisis.

2.2 REASON OF CHOICE

Wicked problems like the climate crisis need a way to correctly understand first and have trust, bring people on the same page, and set goals and measure progress. Hence monitoring is a crucial method to get started with climate action work. Technology has a deep linkage with monitoring. It provides all sensors and input tools and can record and retrieve data efficiently and perform heavy computation on data in less time. But getting wrong values in monitoring can lead to even worse outcomes. Hence care must be taken with technology-aided monitoring.

Financial and economic systems dictate how certain activities are awarded over others. Climate projects need funding and needed behaviour change from all fronts- public, private, and citizen. This change can only come from shifts in financial systems. Technology in its very early phase in Distributed Ledgers, blockchain, and cryptocurrency aims to challenge and re-create existing financial systems. This tech needs to be scrutinised and followed up with the required regulation.

There also needs to be a connection between the monitoring and financial systems—the monitoring informing the financing in a trustable way to form a complete working ecosystem of climate action.

2.3 GAPS

- **Lack of open standards**: As mentioned before, there are many different ways projects do monitoring and financing.
- **Lack of regulation**: There still isn't proper regulation to keep monitoring and financing in check.
- **Need for data trusts**: There is a need for public bodies to transparently show how data is being recorded, how privacy is being respected for there to be trust, shared knowledge, and accountability for monitoring and financing mechanisms.
- **Need for alliance and collaborative approach**: Instead of scattered and different solutions to common problems, there need to be alliances of cities, neighbourhoods, and countries working together across the globe.
- **Confusing variety of sensing options**: There are many different types of sensors and sensing mechanisms available while also requiring expertise in setup and maintenance.

- **Lack of knowledge and use of low-tech and citizen sensing methods**: Many sensing methods involve less technology and computing and are instead citizen and people-focused. But there is a lack of understanding and knowledge of building and supporting such mechanisms.

- **High emissions of tech**: As mentioned before, there is a high amount of material and energy emissions needed to support monitoring and financial systems without proper accounting.

- **Many solutions are still in the early phase**: In the technology world, working has been established where early unverified solutions are being released into the real world as alphas and betas. The "move fast, break things" motto, made prevalent by Facebook, can be very harmful when using technology for climate action.

- **Lack of adoption**: A high number of projects are created with a high budget and effort but cannot get mass adoption and stay as project reports.

2.4 CLIMATE TECH METHOD 1: MONITORING

2.4.1 Background

Why monitor?

Monitoring is often the first step in climate action projects with technology. To make sense of the existing landscape and formulate informed mechanisms to improve the needed systems. The first task is to create a framework to measure, select which metrics to focus on, develop trustable ways to record these metrics and create protocols of constant sense-making. Next comes the role of technology-

- Create data pipelines to form a system to receive the needed data to monitor consistently. This can be done through a lot of means- surveys, interviews, IoT(internet of things) based sensors, citizen sensing, and satellite sensing

- Form protocols for constant measuring and maintenance

- Create data storage mechanisms

- Create sense-making protocols, understand the data and its relation to climate crisis context. This also entails being to make correlations, observe trends and formulate models

Incoming data has encoded complexity with time-based, spatial information micro details and macro details. And then, more complex dimensional layers get embedded when the whole context is added.

Domain	GCOS Essential Climate Variables
Atmospheric (over land, sea and ice)	Surface[A]: Air temperature, wind speed and direction, water vapour, pressure, precipitation (rain/snow), surface radiation budget Upper air[B]: Temperature, wind speed and direction, water vapour, cloud properties, earth radiation budget (including solar radiance) Composition: Carbon dioxide, methane, and other long-lived greenhouse gases[C], ozone and aerosols, supported by their precursors[D].
Oceanic	Surface[E]: Sea-surface temperature, sea-surface salinity, sea level, sea state, sea ice, surface content, ocean colour, Carbon dioxide partial pressure, ocean acidity, Phytoplankton Sub-surface: Temperature, salinity, current, nutrients, carbon dioxide partial pressure, ocean acidity, oxygen tracers
Terrestrial	River discharge, water use, groundwater, lakes, snow cover, glaciers and ice caps, ice sheets, permafrost, albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (FAPAR), leaf area index (LAI), above-ground biomass, soil carbon, fire disturbance, soil moisture.

- (A) Including measurements at standardised, but globally varying heights in close proximity to the surface.
- (B) Up to the stratopause.
- (C) Including nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs).
- (D) In particular nitrogen dioxide (NO_2), sulphur dioxide (SO_2), formaldehyde (HCHO) and carbon monoxide (CO).
- (E) Including measurements within the surface mixed layer, usually within the upper 15m.

Figure 12 - Essential climate variables, taken from Climate Technology Centre & Network[20]

Technology and algorithms have an inherent model to have inputs and outputs, and traditionally this rule dictates how monitoring systems are created. There is also an assumption that the climate action project team has the capacity and knowledge to develop such monitoring systems.

Types of monitoring

1. **Surveys and interviews**: Conduct various on-site and off-site surveys and interviews. Depending on the context, this involves people, materials, and nature in different ways.

2. **Sensor-based**: Deploying sensor networks with the latest technology and uploading data to the internet. Prices of sensors can be cheap and easy to deploy, but it is expensive to create the needed network with sensors. Sensors also require constant care, battery management, and maintenance.

3. **Satellite-based**: Overhead and historical view of the planet created by constant images taken by different satellites revolving around the planet. Satellites are costly and take a long time to deploy and operate.

4. **Citizen sensing**: Citizens and residents can measure and upload data without expert knowledge. There are multiple ways this can be done and compensated. The data usually has a higher margin of error but leads to more care and better management of resources being measured.

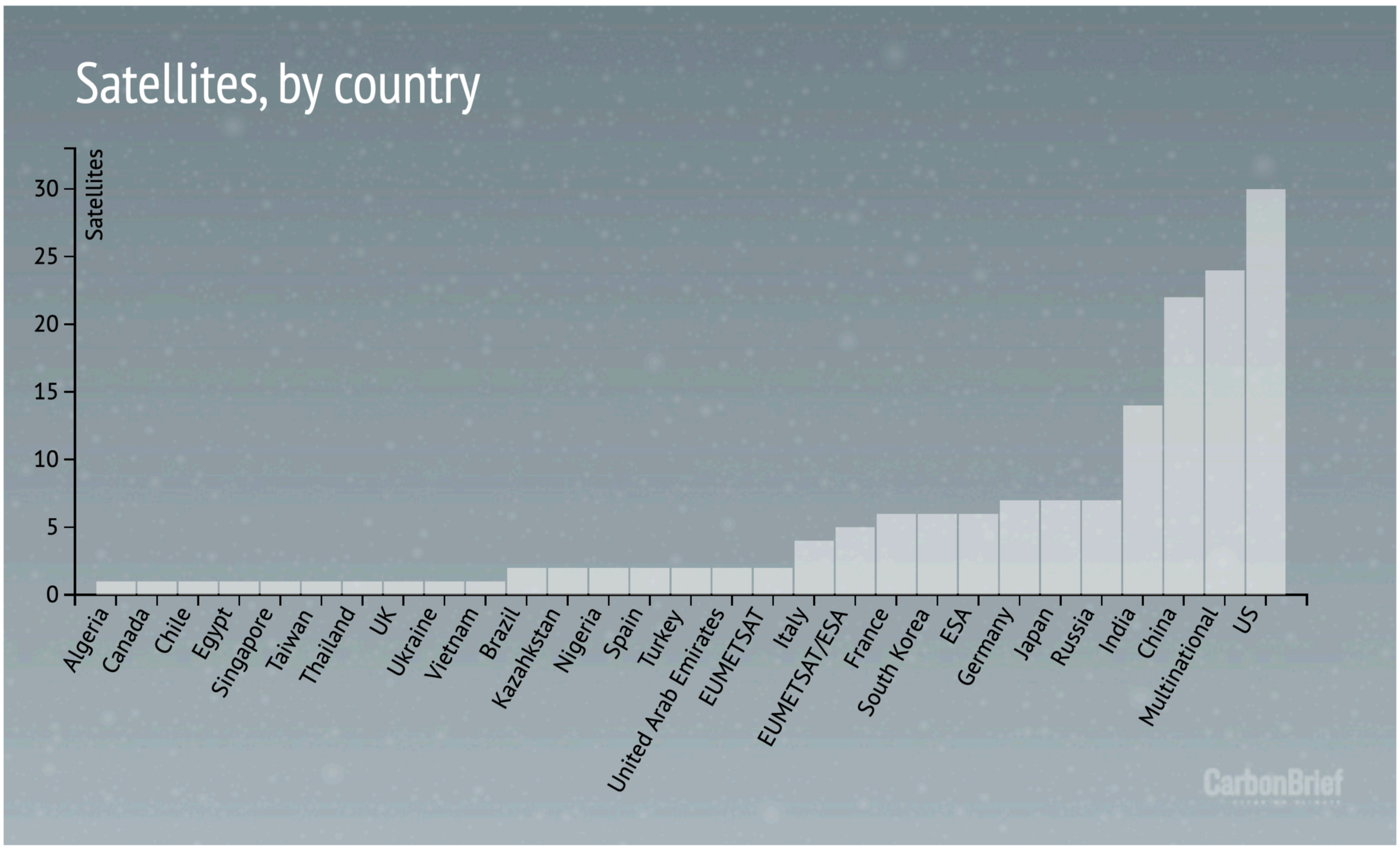


Figure 13 - Satellites, by country, taken from [21]

Each monitoring system offers a different set of advantages and disadvantages. And mostly, there should be a combination of them to form a robust design.

Challenges

- **Challenging complexities**: the task of dissecting needed information from complex systems. And be able to combine measurable and unmeasurable metrics. Data is also constantly in flux and changing, making monitoring even more challenging.
- **The crucial part of the project**: there is a lot of dependence on monitoring systems as it is the building block of climate tech projects, and incorrect data can lead to very costly problems.
- **Different cities in varying progress**: Different cities and countries are on varying levels of progress in their monitoring efforts, some degrees ahead of others.

- **Political issues**: Monitoring can expose underlying societal information that is sometimes censored and kept locked depending on the political situation.
- **Data privacy**: When monitoring data linked with real people can lead to intrusion of data privacy. Facial data information is one such example.
- **Data extractive models**: Data recorded can be misused and sold to advertisement companies, leading to unregulated behavioural changes and other negative trends.
- **Data bias**: There is also evidence[22] monitoring can very easily become biased because of various reasons. These biases are often encoded with systematic racism.

Net-zero/carbon neutrality

'Net-zero' has become the buzzword for the growing concept to reach net carbon neutrality, which is net-zero carbon emissions in the entire lifecycle of any given material or process, but also on a broad level declared by several countries and corporates[23]. Still, there is no clear understanding of being to define and monitor net-zero.

2.4.2 Problems

Single metric driven

Focus on one value in isolation and not see the connected ecosystem. Computers need to break data down to binary language, but not all data is numerically measurable. This leads to monitoring in isolation and a simplified way. If the project focuses only on improving and monitoring that single metric in isolation, it can deter another metric that is not being measured in the system.

Variety of options

A myriad of solutions for monitoring and sensing are available to choose from, as mentioned in the section above. There is a lack of shared knowledge and protocols to guide how to create the needed monitoring systems best.

Digital twins and AI bias

AI or Artificial Intelligence is becoming more and more prevalent in monitoring systems. There are different approaches to achieve this; in simple terms, it is computer-generated synthetic data creation, combined decision-making models.

How it is used for climate projects-

1. Where there are data gaps, AI can generate synthetic data based on models it is taught

2. For creating a digital twin of any object like home or tree, input data is fed into a learning model, which can then be able to make predictions and forecasting

3. To understand nature better, tell details from satellite imagery or predict a home's solar potential using computer vision. AI-assisted techniques can point these patterns better than human monitoring

Data-driven and data-informed approaches

Both terms, data-driven and data-informed, are buzzwords but with different connotations. Data-driven means to use data as the sole driver of decision-making, only using cold hard facts and numbers. Data-informed means treating data as just one of the needed indicators for decision making. It means setting a protocol for data recording and how to do constant sense-making. To always try to dig deeper and ask why data shows a pattern, not just making simple correlations.

Many companies and governments are deciding what they do base on pure data. But data is full of biases and human errors. The models are not even close to perfect yet. Hence, there is a need for a data-informed layer, being honest about biases and errors, finding strategies to account for them, and not being ideal that data will be perfect.

Data can also get entangled with what constitutes "good" performance and "bad." These binary indicators can easily lead to misinterpretations, hiding complexity, and also being deployed in places with different contexts than required.

Emissions

Like other tech solutions, monitoring also has high emissions costs, from the material cost of building sensors to replacing and maintaining them. And a lot of mining processes are needed to create the sensor and its intricate chips. Some of the elements are close to impossible and very difficult to recycle, thus quite hard to create a circular economy[24]. Data storage in data centres and each recording and retrieving operation has its emissions. There needs a heavy amount of time and processing power to train the models, after which they get hosted at a data centre and need constant cloud computation. Even satellites have high material costs and energy needs for their operation.

Trust

Monitoring systems can be made hidden and privately owned by companies. Governments can keep the data closed or sell it at a high price. It is not just the data but also the mechanism being used to record and sense-make, kept locked. This leads to a lack of trust in the data by the people.

Energy poverty

Most sophisticated sensor-based monitoring systems require high energy, and places with energy poverty find it hard to create and sustain the needed monitoring systems.

2.4.3 Literature

The paper *Estimating urban greenness index using remote sensing data: A case study of an affluent vs poor suburbs in the city of Johannesburg*[25] opens up a study done in Johannesburg of using remote satellite data to determine urban greenness. The study first establishes urban greenness and how to index it. And a clear understanding of the existing landscape of tree species and local details of Johannesburg. Followed up by selecting needed satellite input, supplying the data input cost-effectively and ecologically. The paper shows the monitoring process, which involves input data from satellites, which goes through an intricate image classification and allometric formulation computation to calculate the needed parameters. The paper also states the level of accuracy of the system and says the overall accuracy is 96.59%. The study also shows the connection of affluence and poor areas to urban greenness.

The paper *Smart forests and data practices: From the Internet of Trees to planetary governance*[26] explores the topics of Smart Forests from different perspectives. The author discusses various sensor networks available for monitoring forests and their impact. There are novel uses of terminology like 'datafication' and Internet-of-Trees. The paper points out new forms of data emerging from monitoring systems which leads to a new understanding of nature through interconnectedness. Monitoring systems are also linked with accounting and the question of responsibility. Leading to new forms of governance and decision-making such systems need. Topics like automation and UAV drones are also covered in the paper.

2.4.4 Gap

Addressing material and emissions: Literature still lacks full accounting of material and energy emissions and how to do that in a complete lifecycle and standard way.

Political ramifications: Both papers point out political ramifications which data monitoring reveals but still not an explicit method of dealing with it.

Data ownership in the long term: How to convert such studies and experiments into long-term running and evolving ecosystems? Need to formulate clear ownership of such monitoring systems.

Capacity building: It is clear that a high amount of sophisticated knowledge about monitoring systems is required to build climate action projects, but creating such capacity all across the world is still an unclear and challenging task.

2.5 CLIMATE TECH METHOD 2: FINANCIAL SYSTEMS

2.5.1 Background

How financial systems and economics contribute to the crisis

Established financial systems reward heavy industrialisation. All systems are made with an encoded aim of constant growth and ignoring the planetary boundaries. In a way, financial systems also dictate people's behaviours towards what they do for their livelihood and support certain businesses over others by using their purchasing power.

Politics, regulation and lobbying

Financial systems also have a direct connection with politics and governance. Big oil companies have been lobbying to conduct their business as usual and have immense control over regulations using their financial power to ignore the climate crisis.

Change of finance and capital

Distributed Ledger Technologies(DLT) and cryptocurrencies enable new models of capital and money. Not being reliant on governments but rather having a decentralised organisation. Although this is easier to state in theory but in practical terms, the tech is still in the research and early stage of exploration.

Financial risk of not taking any action

An ignored and unacknowledged metric is the amount of financial risk not taking any climate action. This risk entails being able to account for all damages already created because of the climate crisis and more that are coming.

Carbon credits

A carbon credit is a term to quantify environmental change through carbon emissions and make a tradable certificate out of it, which can be exchanged for monetary amounts. Various companies are driving this forward in different ways.

Discount Rate and Statistic

Year	5% Avg.	3% Avg.	2.5% Avg.	3% 95th Percentile
2015	$11	$36	$56	$105
2020	$12	$42	$62	$123
2025	$14	$46	$68	$138
2030	$16	$50	$73	$152
2035	$18	$55	$78	$168
2040	$21	$60	$84	$183
2045	$23	$64	$89	$197
2050	$26	$69	$95	$212

Figure 14 - Social cost of Carbon, taken from Gold Standard report[27]

2.5.2 Distributed Ledgers

What is a DLT?

Distributed Ledger Technology or DLT “is a consensus of replicated, shared, and synchronised digital data geographically spread across multiple sites, countries, or institutions”[28]. It enables decentralised co-ownership of data and decision-making. Being able to establish that the ledger is correct and tamper-proof. It allows a lot of applications and is being used in some climate action projects. DLTs are also very damaging to the environment because of their need for high energy to enable all the mentioned attributes.

What are Smart Contracts?

Self-executing code triggered with given parameters. They are a combination of monitoring systems linked with legal contracts and with a layer of automation to smoothen bureaucratic problems. Smart contracts are part of and enabled by most DLT solutions.

Possibilities of DLT

The status quo in data-rich cities is centralised databases maintained by city councils, and data comes from yearly assessments, surveys, and models. Some of these databases are open and free to use, while some are closed and available for a cost while some are kept for confidential uses only.

- **Ownership**: centralised databases are owned by one party, whereas DLT enables shared co-ownership, facilitating the creation of a civic infrastructure.
- **Trust**: the data recording mechanisms are not always fully transparent; it is hard to tell when and how data changes and if there is some manipulation. DLTs, in theory, give full transparency to this and hence help formulate trust.
- **Financial value**: A project like TreeZilla[29] can efficiently generate eco-benefits of a tree, but DLTs can go one step further and mint currency/tokens based on set protocols, facilitating the nature-based market.
- **Live data**: as there is a move further and further to sense our physical and built world using satellites, IoT sensors, and citizen-sensing, DLTs connected with smart contracts can use this sensor data to keep the system consistently updated and regulated to set limits.
- **Inclusion**: Because DLTs make things transparent, including the underlying financial models, and also, at least for now, do not have the bounds or limits of entry that are in the current financial world. Thus DLTs make it easy for everyone to invest. That being said, DLTs can also go through power dynamics if not set correctly.

- **Governance**: DLTs also enable us to have new governance and decision-making methods.

DLTs are still novel and developing technology. Blockchains, a very popularised term, is just one way to create DLTs, but there are plenty more techniques gaining more and more traction. DLTs are in the research phase, trying to harness their full utility while also exposing their high energy emission. Centralised databases are still beneficial in their needed application, as they are much faster and consume way less energy than DLTs.

2.5.3 Problems

Perceived static state

Financial systems are very tough to change as they are interlinked to all human activity and impact people, governments, and corporates directly. Thus there is a perceived belief that financial systems are fixed and not changeable.

Hard to make large scale change

There is a requirement for institutional shifts in financial systems for the needed large-scale and long-term changes required for climate action.

Lack of transparency

Financial systems have intentionally made it hard to understand, keep wealth in the hands of few, and keep the system closed. There is a lot of funding and support going towards big companies doing climate violations; there is a clear transparent need to understand these transactions better.

Carbon credits issues

Carbon credit markets still have not reached full maturity. The process takes a long time and involves bureaucracy. It is hard to trust the carbon credit market without full transparency. There is also the danger of over-financing environmental projects and making critical decisions from a monetary perspective and not environmental.

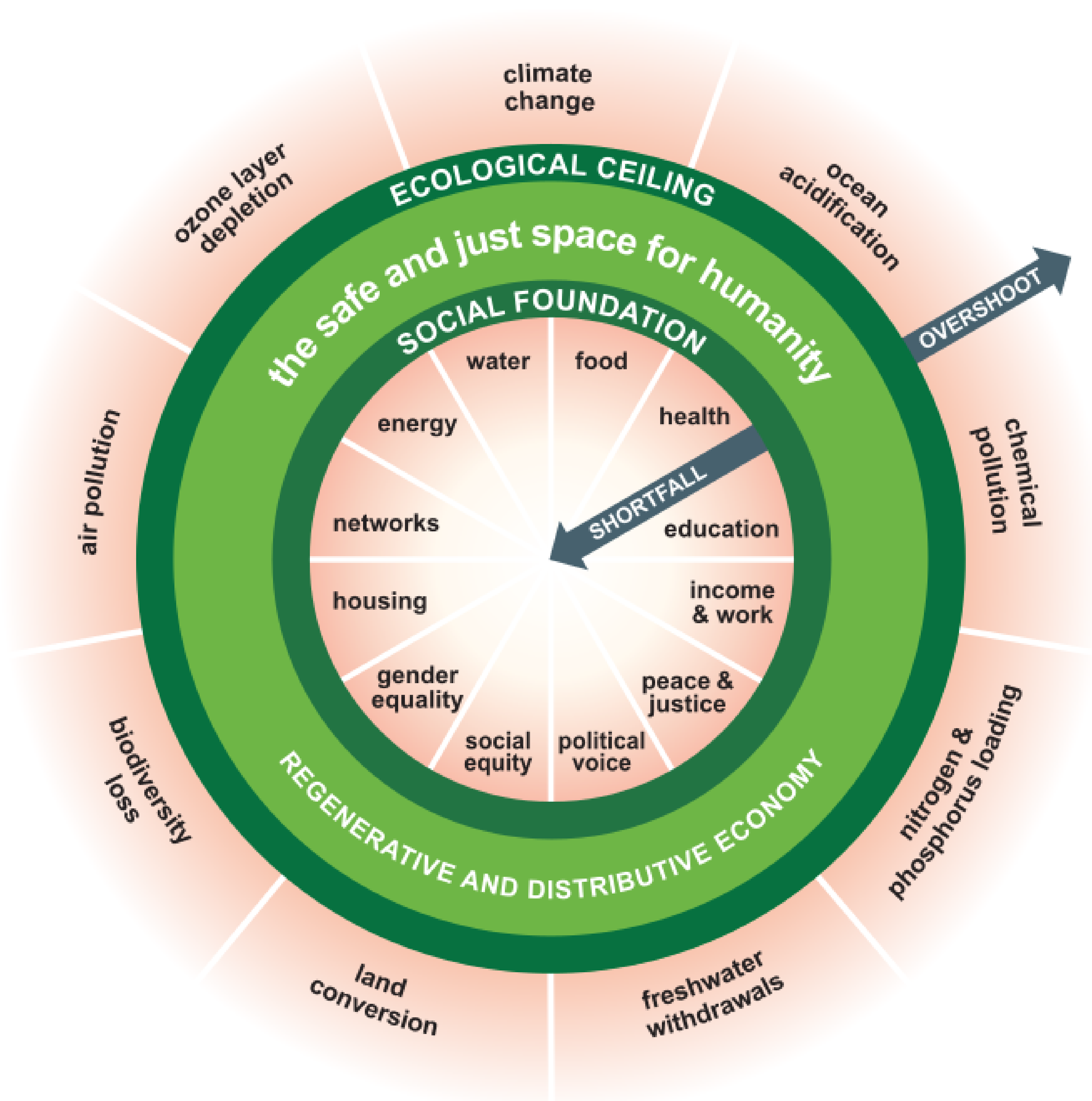


Figure 15 - Doughnut Economics taking into account social and planetary boundaries, taken from Doughnut Economics Action Lab[30]

DLT issues

DLT and its underlying algorithms require a colossal energy infrastructure to work. Not only that, they assume that the world has ample and equal access to technology, energy, and the internet. All these are significant concerns in the wake of the climate crisis.

- The direct connection between energy and wealth needs to be challenged, not perpetuated. One of the most popular DLT systems is Bitcoin, and its working and consensus algorithm called Proof of Work is built to use energy-intensive operations for its working. There has to be a more ecological solution for consensus mechanisms to make DLTs fully viable for climate action. It is often assumed that the price of energy is the same in all places, and it is not considered what happens to energy poverty-stricken areas. Bitcoin has got a sense of centralisation with most energy-hungry ‘mining farms’ in China for a decentralised currency.

- DLTs are progressing rapidly, but some solutions are very technology-heavy and technocratic. There is a lot of focus on what the tech can enable. And then such tech is pushed onto the world without accounting for social issues, which financial systems are a big part of. “The environmental movement needs to learn when it comes to technology — precisely not that the whole problem is bad technology and the solution is better technology, but that we have to escape from the tendency to think about technology and society separately. We need to think techno-socially.”[31]

- There is an evident lack of access to such technologies in the Global South[32].

- A lot of ongoing high usage comes from hype and speculation. Most people are looking at these quick money-making schemes and trying to convince everyone else to participate. The industry is filled with a lot of scams. These scams create false value for DLTs and cryptocurrencies.

- On a practical level also there are design issues. It is still hard for everyone to understand the true value of DLTs and how they work. Possibilities of corruption and bad actors through invalid data entry into the DLT. To manage DLT based apps requires various hard-to-use solutions to do key management, pay high transaction fees, and slow networks. And decentralisation itself is challenging to implement in practical settings with fair decision-making and accountability.

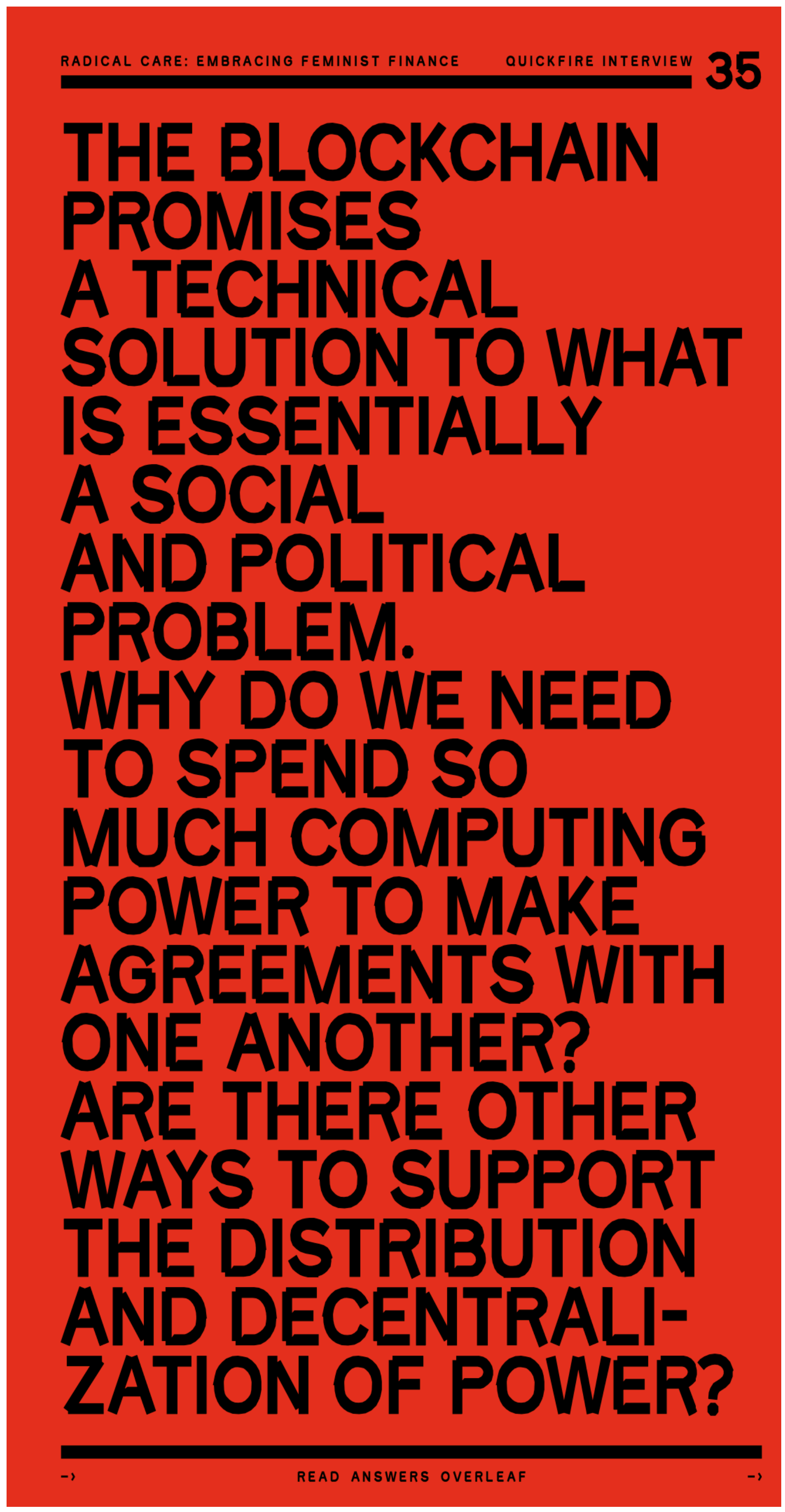


Figure 16 - DLT provocation taken from Radicale Care: Embracing Feminism Finance[33]

2.5.4 Literature

Regen Network has published its white-paper titled *Regen Network Economics Technical Paper An Ecological Market-Commons, Secured by Proof-of-Stake*[34], which shows how DLTs can become the connection between ecology and economy. They suggest “a community dedicated to maintaining a decentralised open ledger of ecological health information to serve as the basis for conditional agreements between parties is an essential building block for a new phase of the global economy that accounts for ecological health and invests in ecological regeneration as the cornerstone of healthy business and governance.”[34] The focus is to measure and financialise public good outcomes through DLT.

The paper highlights how current systems are based on short-term profits and miss capturing long-term systems’ true wealth. It recognises that economic processes need to be intervened to address the climate crisis. Regen wants to reinvent how agriculture and land use are thought of and economically accounted for through ubiquitous access to high-quality ecological information.

Its technology is based on the Proof of Stake consensus algorithm, which in theory has fewer emissions than Bitcoin’s Proof of Work. The paper highlights how the technical stack of the system involves Oracles, sensors, and crypto-economics. There are also points covering community involvement, ecology state protocols, and agreements. The paper highlights how DLT offers novel financial techniques like staking, validator rewards, open token allocation, and governance. And how these techniques help Regen achieve its goals.

2.5.5 Gap

Lack of access: Even though the paper talks about community efforts, the DLT tech relies on access to various kinds of technology, smartphones, and internet infrastructure. There is still not full access to this in the Global South.

Emissions accounting: Regen, as it relies on Proof-of-Stake, has fewer emissions than other prevalent DLT systems but still has significant materiality and emissions involved, which need to be fully accounted for.

Early-stage: Regen Network and other DLT solutions are still in an early phase and based on several assumptions.

3. CLIMATE ACTIONS PROJECTS THROUGH DARK MATTER LABS

3.1 DARK MATTER LABS

Dark Matter Labs[35] is a non-profit organisation focused on the strategic discovery, design, and development, working to transition society in response to the technological revolution and climate breakdown. They work with different partners across the world on mission-driven projects. Dark Matter is a growing community of diversely skilled people from different places who share a common passion. ‘Dark matter’ refers to the invisible structures in our society.

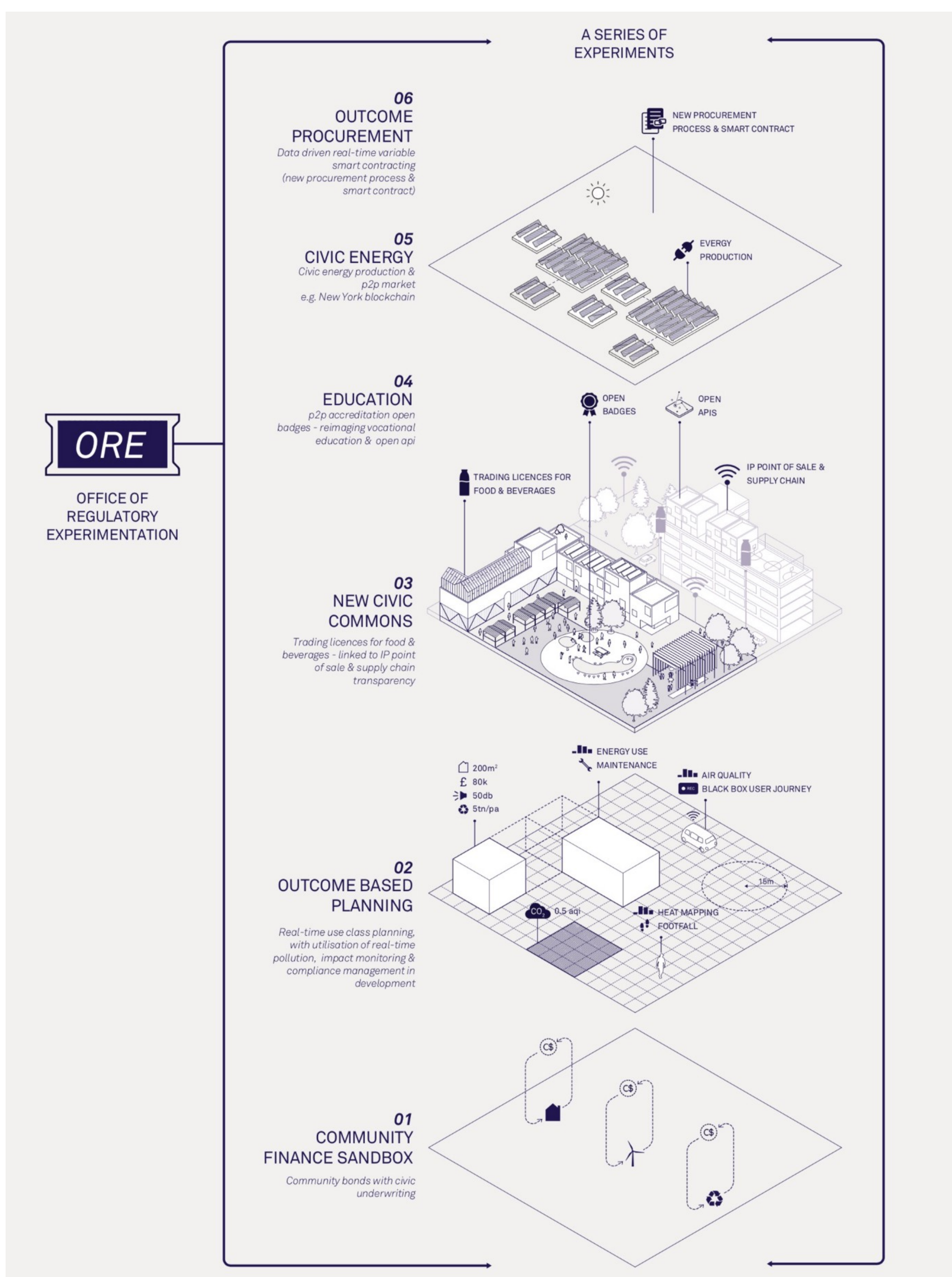


Figure 17 - Office of Regulatory Experimentation, created by Dark Matter Labs[37]

Dark Matter has legal entities in the UK, Netherlands, South Korea, Canada, and Sweden and a distributed team across many countries. Their set vision from January 2020 was published as an open letter called *Amsterdam 2019–2020: Letter to our Future*[36]. The letter highlights the need for a *Boring Revolution*[37] to slowly understand hidden structures behind the systemic failure of infrastructures in the society leading to the climate crisis. And then through experimentation and working with local councils and citizens to transition and improve ecosystems around. A lot of funding for projects in the EU comes from EIT Climate-KIC[38].

3.1.1 Dark Matter's missions

The framework of the mission comes from Mariana Mazzucato's published report from the *2018 Mission-Oriented Research & Innovation in the European Union*[39]. The report highlights the need, granularity, methods, and selection criteria for such missions. Dark Matter has been using it as one of the tools to guide their work.

Dark Matter Lab's current missions

The list of missions is an evolving and changing framework helping navigate complexity in projects. The changes come as new knowledge is added or a mission breaks into two smaller missions.

The current list of missions contains-

1. **Cities**: Re-thinking of cities as a space. There is work on topics from affordability to systems of care. And according to city context helping city councils reshape structures to enable home renovations, shared assets, accessible services, and so on.

2. **Civic Financing**: Understanding the power structures behind the unfair division of wealth and systems that propagate that and shift that towards commons-based civic structures.

3. **Education**: A distributed sense of knowledge sharing, discourse, and enabling dialogue between communities and enabling voices from the community.

4. **Food Systems**: Topics ranging from soil health to food production systems and livelihood of farmers.

5. **Spatial Justice**: Retrofitting of homes and the communities around. This topic is discussed in detail in Retrofit project section.

6. **Governance Innovation**: Understanding power structures and how to make them more participatory and citizen-driven.

7. **Long-termism**: Making people think much more long-term and set ideas and initiatives which the planet can harness in the next 200 years.

8. **Mental Wealth**: Focus on the mental health of the people and community. Navigating through this complexity together.

9. **Natural Assets**: Focus on nature, and how to best take care of it, so it takes care of us—discussed in detail later.

10. **Operations**: Internal operations of Dark Matter, care for each other, how Dark Matter people work, self-critique, finance, and future vision.

These missions are intentionally set to be interlinked, and there is a lot of knowledge sharing between them. It is a framework that helps us guide and understand the projects and their entailing work.

3.1.2 The author's role at Dark Matter Labs

The author started working with Dark Matter Labs in September 2020 amid COVID 19 pandemic, getting on board to remotely distributed teams, finding shared context, and helping with ongoing projects and challenges.

The author's background is in Computer Science. With knowledge of low-level computer systems work on building applications. Working in Silicon Valley gave them a perspective of how technology impacts society and how wide of an imbalance it is creating. After that, they worked in a big design consultancy, working with organisations in Finland through their digital transformations and culture restructures. At Aalto University, the author profoundly researches topics like decentralisation, blockchain and cryptocurrencies, climate crises, design justice, data justice, and tech materiality.

At Dark Matter Labs, the author's role is researcher, taking ownership of the use and feasibility of the technology in projects, building prototypes, data science, and more tech development as projects evolve. They are working along a diverse team covering design, urban policy, research, facilitation, data analytics, visual communication and engagement, architecture, strategic design, and service design.

3.2 TREES AS INFRASTRUCTURE

Trees as Infrastructure(TreesAI) is part of the Nature-based Solutions mission or NbS, a term created to combine all efforts to work with nature. The term is being used in Dark Matter Lab's collaboration[40] with Scotland and other works across the EU.

The current relationship with nature and our prevalent economics and business systems has been very exploitive. It ignores the planetary bounds and causes tremendous damage to all bio-systems. Activities like clearing forests, mining, excessive animal farming, dumping waste, and more have degraded the health of nature around us. NbS focuses on fixing this relationship and creating long-term infrastructures to preserve and protect nature.

NbS is a range of projects to better understand nature and its complex ecosystems and use more natural assets to help alleviate the climate crisis. Projects include forest reforestation, managing urban trees, rewilding gardens, better water management, and soil restoration. Finding the ecological solutions for all materials in use, from packaging to construction. The research also stems from regenerative patterns, biomimicry, mycorrhizal network, etc.

Trees as Infrastructure focuses on creating an open framework for the care and maintenance of urban forests through data-informed novel investing mechanisms.

3.2.1 The problem

Urban trees are seen as maintenance costs on city balance sheets ignoring all the benefits trees bring. Usually, there are scattered and one-time investments from local councils and private investors on tree plantation and maintenance projects that are not ample for good long-term health. Urban forests need long-term planning and regular maintenance to thrive and sustain as required. One-time donations also make it hard to have viable salaries for tree caretakers. Understanding which species of trees to plant and in which location is also a very complex decision.

3.2.2 The potential

There is potential to form urban trees as financial assets based on real-time data. Understanding the benefits that trees bring to the city using innovations in technology and Decentralised Finance(DeFi) makes the ecosystem more open to investing and gives financial returns based on the positive impact trees are producing.

3.2.3 Ecosystem services

Ecosystem services refer to all the potential benefits a natural ecosystem can provide the environment and organisms living in it. Some examples are carbon sequestration, improving air quality, preventing flooding, reducing energy needs, green job creation, reducing crime, and more.

3.2.4 Existing process in urban forest projects

1. Conduct detailed surveys in a given city to understand the landscape
2. Form project methodology outlining monitoring systems, protocols, formulas, and theoretical base
3. Get methodology verified by an established carbon credits authority. An authority that will give out money in exchange for validation of carbon and other metrics
4. Kick-off project, setup needed infrastructures and human networks
5. Make needed measurements periodically as per methodology. Calculate the amount of carbon sequestered and stored in the trees
6. Validate given metrics with carbon credits authority and receive funds in return

3.2.5 Challenges

1. Project ownership and setup are unclear and vary in different projects. There is a lack of set structure between the city council, NGOs, for-profit companies, and citizens.
2. Be able to capture location-specific context details in the model(existing older species, land and soil patterns, climate zone, city topology, etc.)
3. Current methods are survey-based, how to move towards the robust sensor, satellite, and AI-based.
4. Dependency on carbon credits authority takes a long time to get the needed validations and involves a very bureaucratic process.
5. Satellite data is readily available, but difficult to get micro tree-level info. There are some AI-based solutions here and also solutions using live satellite data.

6. Lack of capacity and knowledge in city governments for execution.

7. Further lack of clarity of infrastructure ownership when external agencies or consultancies are involved.

3.2.6 Existing standards

i-Tree model[41]- A collaborative effort by USDA Forest Service and other partners to create open-source detailed models and tools for urban and rural forestry assessment and tracking. The tools are very useful for understanding the data parameters needed and calculating the benefits that trees are giving to the area. There are survey-based tools, but they can be forked and used in ample ways.

Tree Information

Use this table to help guide your field data collection decisions: The Description column provides more information about each data variable. The extra model components shown in the right-hand columns require certain optional data to be collected. The optional data that must be collected for each extra model component are designated by an "x".			Energy	Pests (IPED)
Data Variables		**Description**		
Minimum required fields				
Species		Identify and record the species and genus names of each tree	REQUIRED	
DBH		Exact measurement or categories of the tree stem diameter at breast height for each tree	REQUIRED	
General site fields				
Land use		Land use type in which tree is located		
Status		Status of tree as planted or self-seeded		
Distance to plot center		The distance from the tree to plot center		
Direction to plot center		The direction from the tree to plot center		
Street tree/non-street tree		Identify if tree is a street tree or not (Y/N)		
Public/private		The classification of each tree as city managed (public) or not (private)		
Cover under canopy	Percent impervious	The percent of the area beneath the drip line of the tree that is impervious		
	Percent shrub	The percent of the area beneath the drip line of the tree that is shrub		
Tree detail fields				
Total tree height		Height from the ground to the top (alive or dead) of the tree		
Crown size	Live tree height	Height from the ground to the live top of the tree		
	Height to crown base	Height from the ground to the base of the live crown		
	Crown width	The width of the crown in two directions: north-south and east-west		
	Percent crown missing	Percent of the crown volume that is not occupied by branches and leaves		
Crown health	Dieback	Estimate of the percent of the crown that is composed of dead branches		
	Condition	Estimate of the condition of the crown recorded as 100 minus the percent of the crown composed of dieback (i.e., dead branches)		
Crown light exposure		Number of sides of the tree receiving sunlight from above (maximum of 5)		
Energy	Direction	Direction from tree to the closest part of the building	x	
	Distance	Shortest distance from tree to the closest part of the building	x	
Management fields				
Maintenance recommended		User defined general maintenance recommendations (e.g. routine prune) for the tree		
Maintenance task		User defined priority maintenance tasks (e.g., pest treatment) for the tree		
Sidewalk conflict		Extent of damage to sidewalks from nearby trees defined by user		
Utility conflict		User defined potential or existing conflicts between tree branches and overhead utility lines		

Figure 18 - i-Tree data model[41]

i-Tree has created the UFORE methods, specifically catered towards the urban forest. Consisting of these parts[42]-

UFORE-A: Anatomy of the Urban Forest -- quantifies urban forest structure (e.g., species composition, tree density, tree health, leaf area, leaf and tree biomass) based on field data.

UFORE-B: Biogenic Volatile Organic Compound (VOC) Emissions -- quantifies: 1) hourly urban forest VOC emissions (isoprene, monoterpenes, and other VOC emissions that contribute to O_3 formation) based on field and meteorological data, and 2) O_3 and CO formation based on VOC emissions.

UFORE-C: Carbon Storage and Sequestration -- calculates total stored C, and gross and net C sequestered annually by the urban forest based on field data.

UFORE-D: Dry Deposition of Air Pollution -- quantifies the hourly amount of pollution removed by the urban forest and associated percent improvement in air quality throughout a year. Pollution removal is calculated for O_3, SO_2, NO_2, CO, and PM_{10} based on field, pollution concentration, and meteorological data.

UFORE-E: Energy Conservation – estimates effects of trees on building energy use and consequent emissions of carbon from power plants.

Each part explains the theory and formulas needed to make the calculations in detail.

Some negative aspects of the i-Tree models are that they are catered more towards the USA, and most baseline data available only include US-based states. Thus it can be hard at times to use it in the EU. Also, some of the tools are Windows desktop-based and not well designed. There is potential to adapt and evolve i-Tree models with modern technology applications.

Gold Standard- “Gold Standard for the Global Goals sets the standard for climate and development interventions to quantify, certify and maximise their impact -- creating value for people around the world and the planet we share.”[43] Gold Standard has created a market for carbon credits and environmental projects. They help certify the impact of a climate action project and convert impact to financial returns. They also work with corporates and help with carbon offsetting projects. Gold Standard is working on a more technologically advanced certification system called SustainCERT[44]. There are also similar standards like Verified Carbon Standard[45] and other local entities doing similar work as Gold Standard and trying to create a voluntary carbon market.

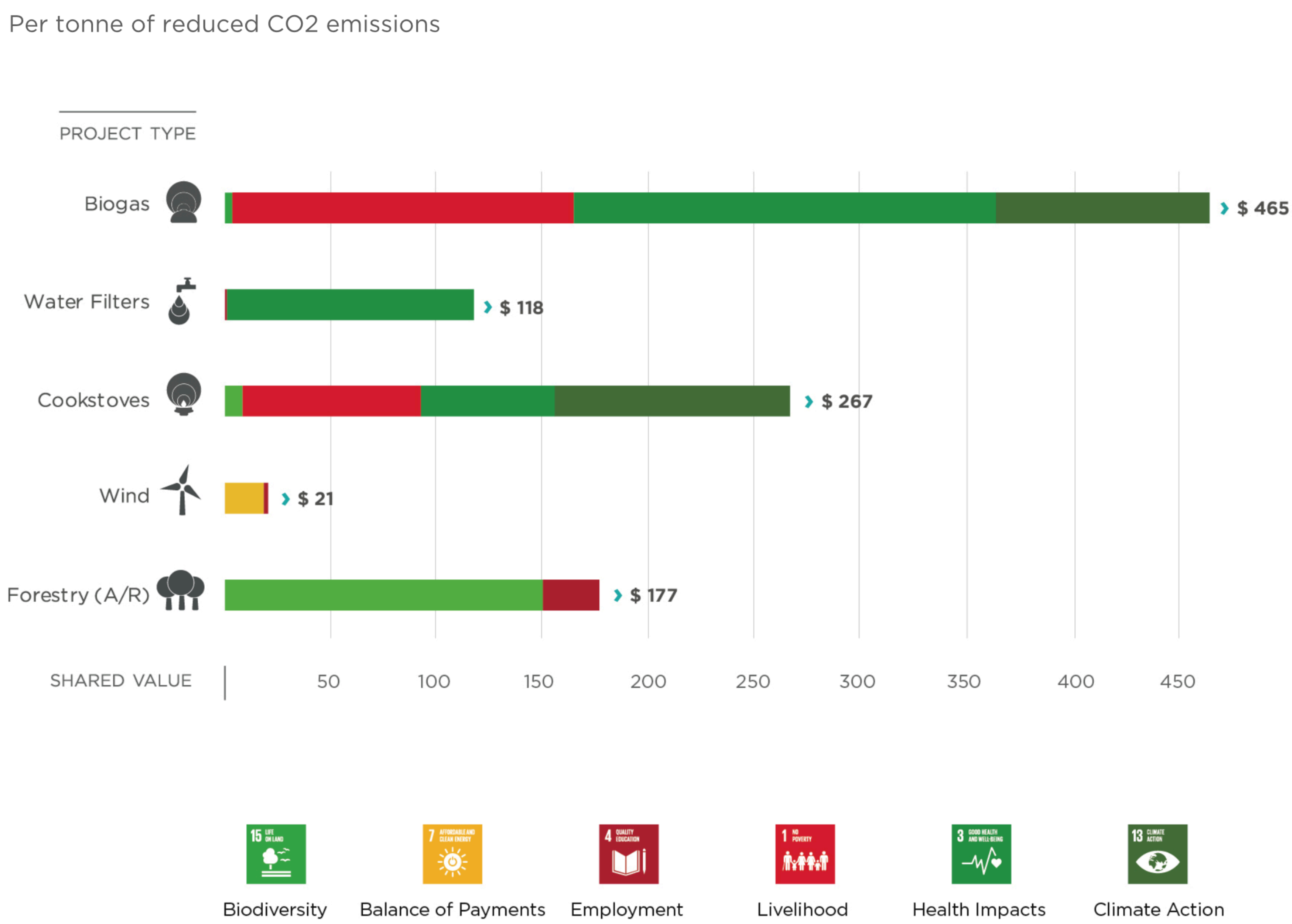


Figure 19 - Gold Standard project monetary values, taken from Gold Standard report[27]

3.2.7 Primary data inputs

- Tree species
- Tree DBH(diameter at breast height)
- Tree canopy
- Climate of area
- Details of land around the tree

It is essential to understand the local contextual details like the history of the land and soil, which tree species already exist nearby, which species are available to plant, what kind of building structures are nearby, and the plans of the built environment around the urban forest.

Monitoring and impact framework being developed in the project

1. Understand and compute the existing landscape of urban trees in a city.
2. Make connections and collaboration with the local city council.
3. Form baseline numbers.
4. Formulate a mechanism to be able to record the data inputs mentioned above. This mechanism will combine different data monitoring mechanisms mentioned in the previous chapter. Important to note that citizen sensing helps create a human care network around the urban forest and trees, which significantly improves the tree survival rates and helps generate more appreciation of urban nature.
5. Involve people from city councils at each stage through interviews, workshops, and co-design needed solutions together.
6. Invite local city partners and citizens for continued collaboration.
7. Create and test prototypes. Formulate needed work culture and capacity in city council to own and operate the required mechanism and applications.
8. Many details and variables will need constant adjustment based on the context.
9. Create needed tech infrastructure.
10. Slowly deploy and scale the application in the city and beyond.

3.2.8 Financial framework being developed in the project

The financial framework has two parts-

1. First is working with carbon credits issuing authority and validating created methodology to convert measured impact to financial gains. This is needed as a bridging step.
2. The second is to innovate and create a new form of impact monetisation system using Distributed Ledger Technology mentioned in the previous chapter. To formulate impact tokens created upon validation of metrics from tree monitoring systems and directly transfer them to the beneficiaries. This solution is still speculative as the world of DLTs and cryptocurrencies is slowly evolving and

getting more stable. There is also a significant concern of emissions of this system, as mentioned before.

The project entails creating an investment portal where all types of investors- city council, local citizens, and corporates can log in and invest in the urban nature of their city and receive monetary returns based on the health of urban nature. The portal will be well designed, transparent, and easy to understand. To make investments more accessible and easy to understand, and create more connections between people and nature.

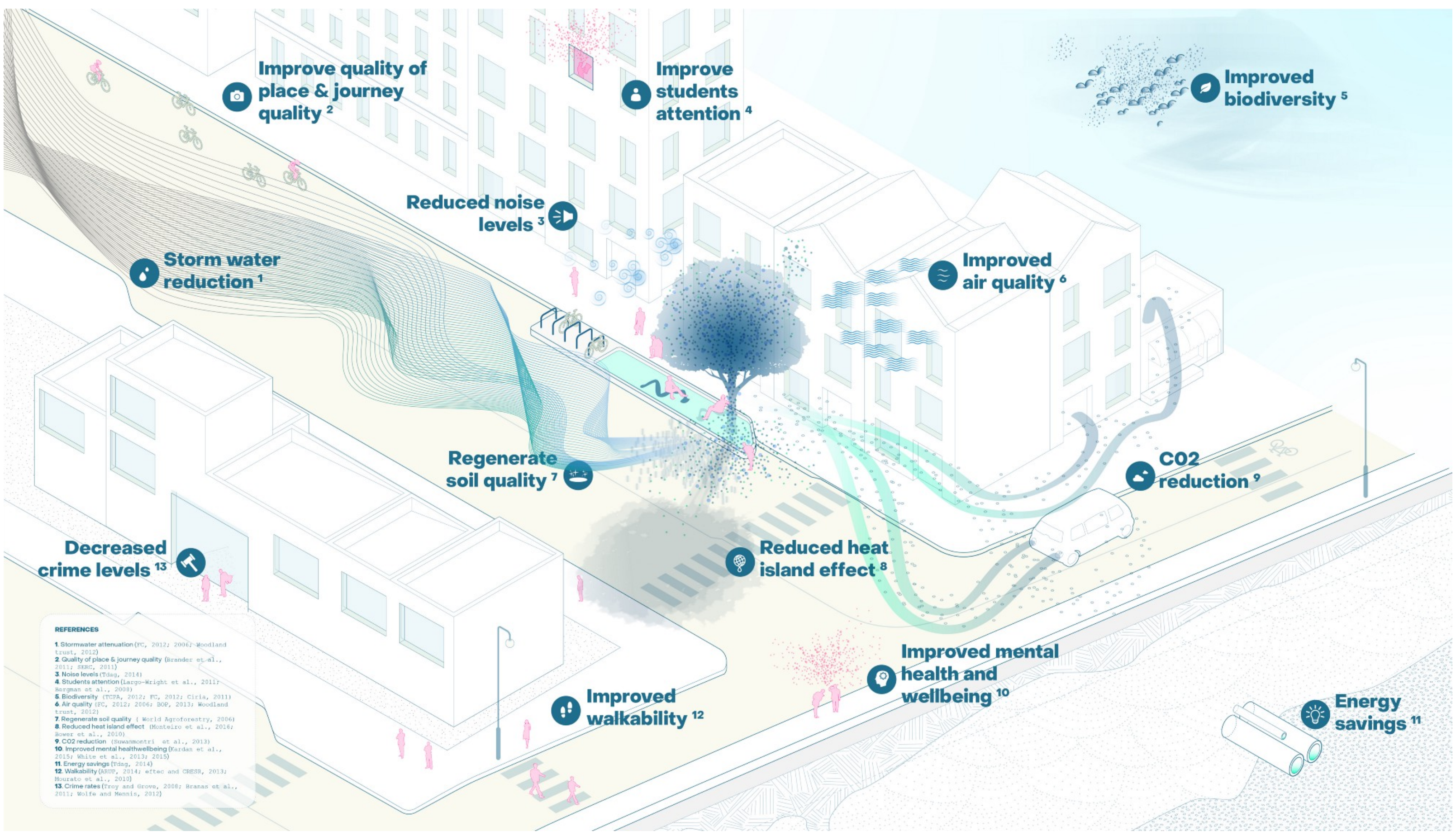
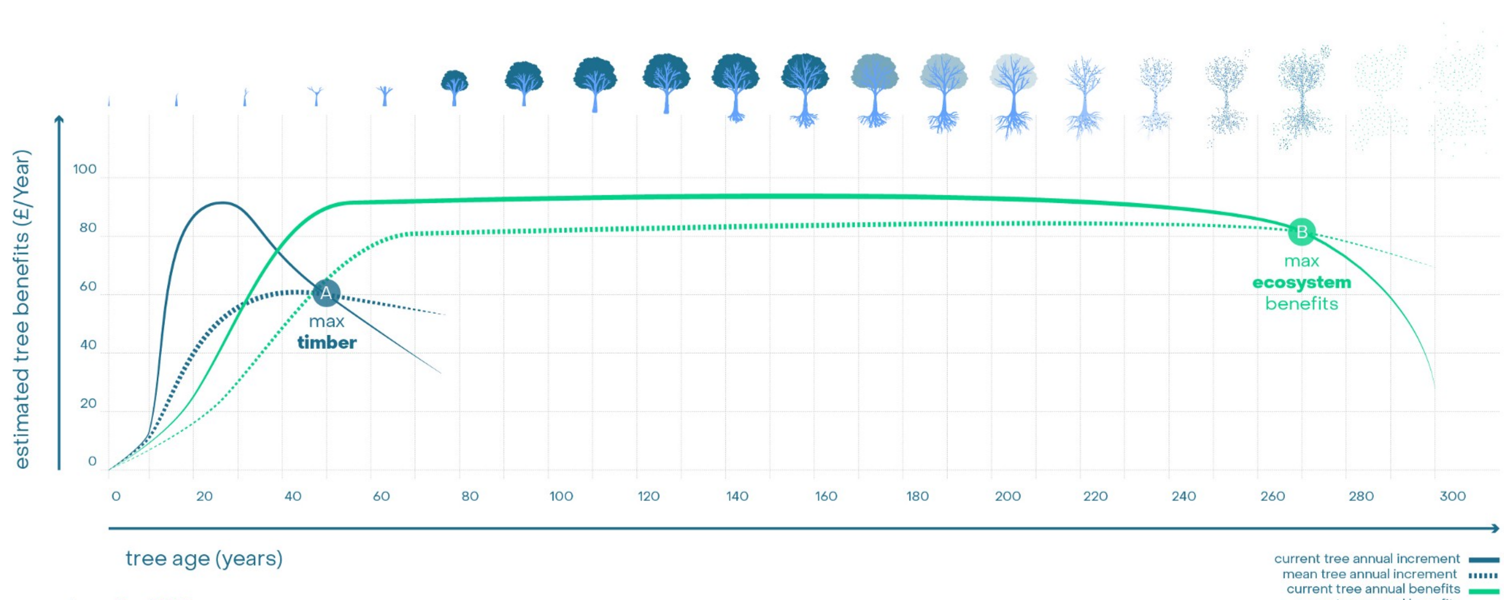


Figure 20 - Tree Ecosystem services, created by Dark Matter Labs[46]

Figure 21 - Tree estimated € benefit, created by Dark Matter Labs[46]



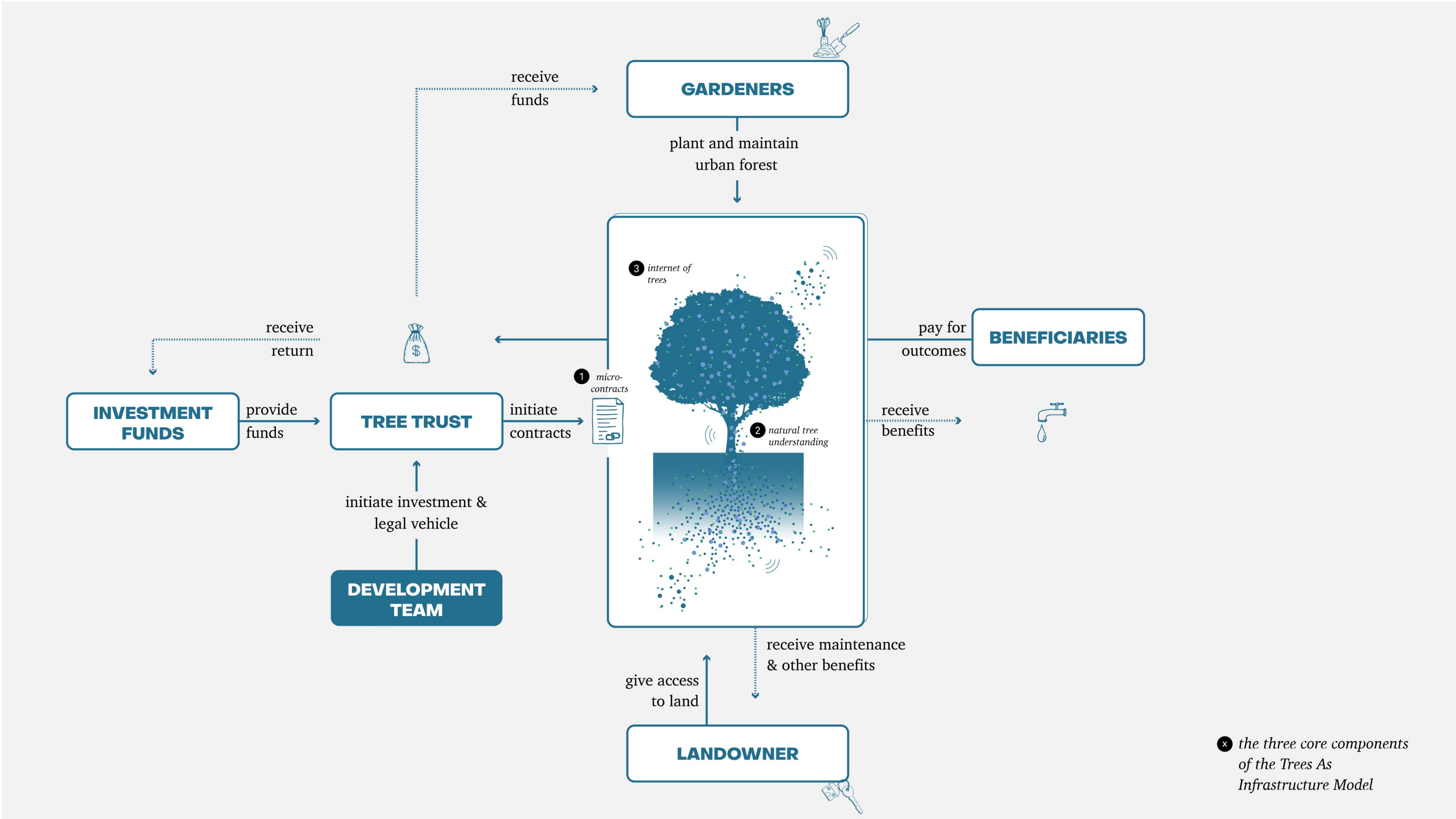


Figure 22 - TreeAI components, created by Dark Matter Labs[47]

3.2.9 Experiments conducted in the project

1. Formulate and create blog series with the project idea and share it worldwide to get feedback, and the idea is perceived. The blogs[46] [47] obtained an excellent response and allowed us to get more people on board with the project.

2. Engage officials from city councils through interviews and workshops. Understand what their needs, budgets, and priorities are.

3. Check what existing open data is available, check open-source projects already doing something that can quickly prototype and test concepts.

4. Using the i-Tree model, create projects and simulations for the project.

5. Use AI and agent-based modelling to generate synthetic data where there are data gaps and use those to estimate impact metrics.

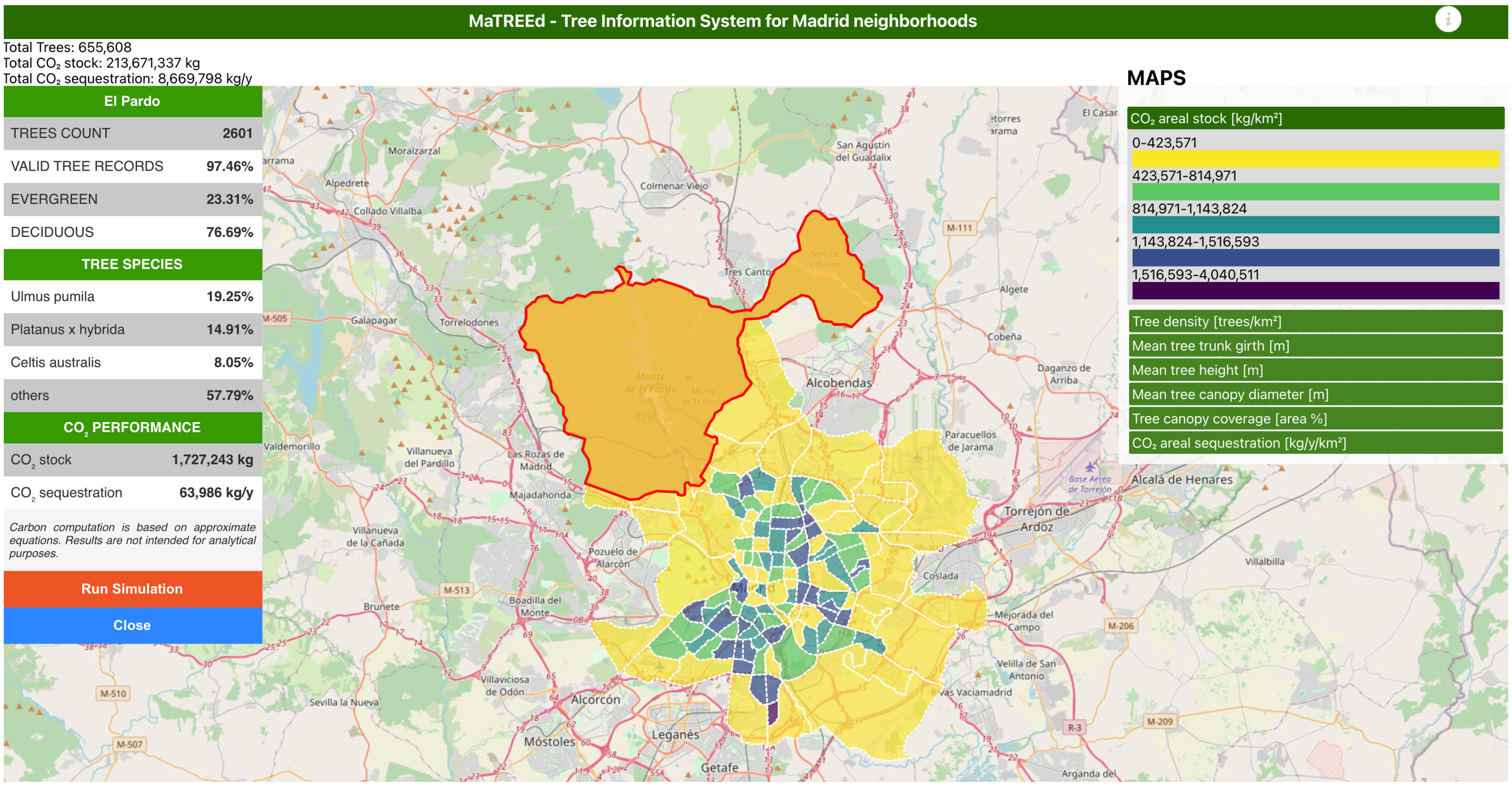
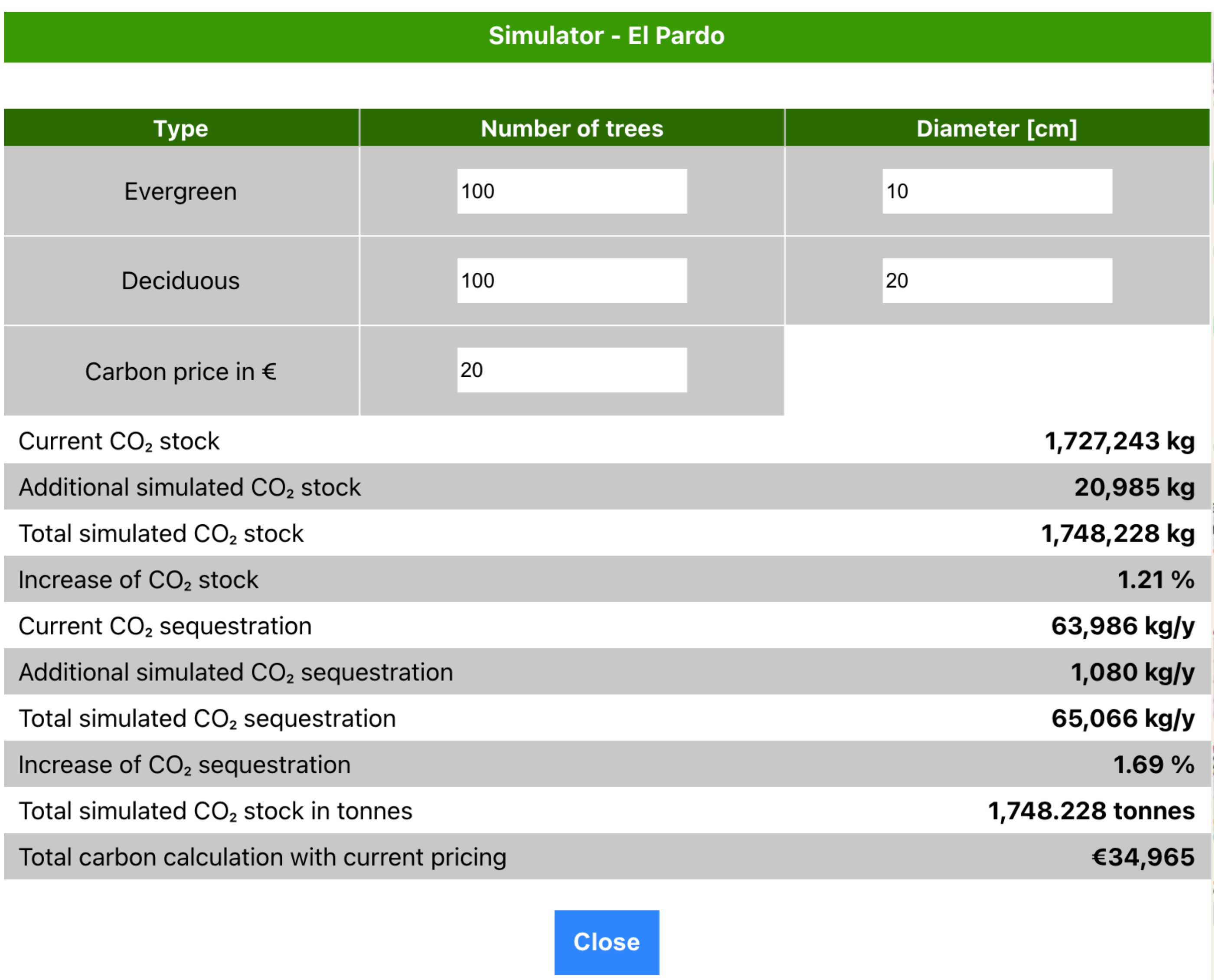


Figure 23 and 24 - Code experiments done by the author using a forked project based on Madrid tree data[48]



Simulator - El Pardo

Type	Number of trees	Diameter [cm]
Evergreen	100	10
Deciduous	100	20
Carbon price in €	20	

Current CO_2 stock	1,727,243 kg
Additional simulated CO_2 stock	20,985 kg
Total simulated CO_2 stock	1,748,228 kg
Increase of CO_2 stock	1.21 %
Current CO_2 sequestration	63,986 kg/y
Additional simulated CO_2 sequestration	1,080 kg/y
Total simulated CO_2 sequestration	65,066 kg/y
Increase of CO_2 sequestration	1.69 %
Total simulated CO_2 stock in tonnes	1,748.228 tonnes
Total carbon calculation with current pricing	€34,965

Close

Brief findings of i-Tree Glasgow report from 2013[49]

- Glasgow has a high density of trees compared to cities in England, but lower than in neighbouring Edinburgh.
- Glasgow has a high proportion of large trees (60cm+); a lack of medium sized trees puts this at risk in the future.
- Vacant land supports a significant number of trees in Glasgow, second only to parks. This could be a major consideration in development plans, as vacant land is most likely to be developed.
- Up to 32% of Glasgow' urban space is available to plant new trees or shrubs.
- The ecosystem services provided by Glasgow's urban trees were estimated to have a value of £4.5 million per year.

3.2.10 Project status

Trees as Infrastructure has received a grant and entry into an accelerator program in 2021. Work is ongoing to solidify both the monitoring and financial framework and form relationships with partners on the ground.

The plan is to finalise a pilot city and start working there in full scope and, at the same time, forming more relationships with two other cities and applying the learnings from the pilot city there.

Once Trees as Infrastructure has been established and is working stably, the goal is to expand it further to Nature as Infrastructure, adding in soil, gardens, food systems, water, and other natural assets into the system.

3.3 RETROFIT AND THE BUILT ENVIRONMENT

Buildings and homes are in a constant state of degradation and need to be maintained. Many buildings were constructed a long time back and have a high potential of reducing energy consumption by upgrading to renewable-based energy, grid systems, heat pumps, double glazed windows, etc., depending on the area and its topology. Many construction companies want to clear land and make new constructions. Retrofitting can help ease the demand in a climate-oriented way.

Dark Matter Labs has been working with different cities in the EU to understand how much budget the city has, the main issues the citizens are facing, the state of buildings and energy landscape, and how to build shared civic assets in the city.

Retrofitting means something different in different city contexts, so it is hard to generalise. But the main goal is to elongate building and community health by integrating maintenance in the living process.

One of the insights from the project has been that retrofitting measures can be best only utilised when done in a collective and community way and not individual scattered projects, which has been the current case. Technology can be used here to use existing data to find such patterns to make needed collectives and execute retrofitting projects systematically.

Digital infrastructure can be used for making people aware, take decisions collectively, and understand what retrofitting means precisely for them and their community. To add a layer of technology for understanding their community, its carbon impact, and health parameters better, and interface with shared assets. It is important to note that such a digital infrastructure must be made in the most accessible ways. It must be accompanied by on-the-ground and offline presence and alternate routes to participate. Tech can also be used as a registry for all materials used in the retrofit work process to understand the net impact. Topics like tech materiality and cloud carbon must be considered with full accountability.

This infrastructure must also be connected with a bottom-up, resident lead approach. As well as include community measures like shared resources, collective decision making, education, community programs, and a collective fund structure.

3.3.1 Existing standards

EPC: EPC or Energy Performance Certificate is a rating scheme for buildings.

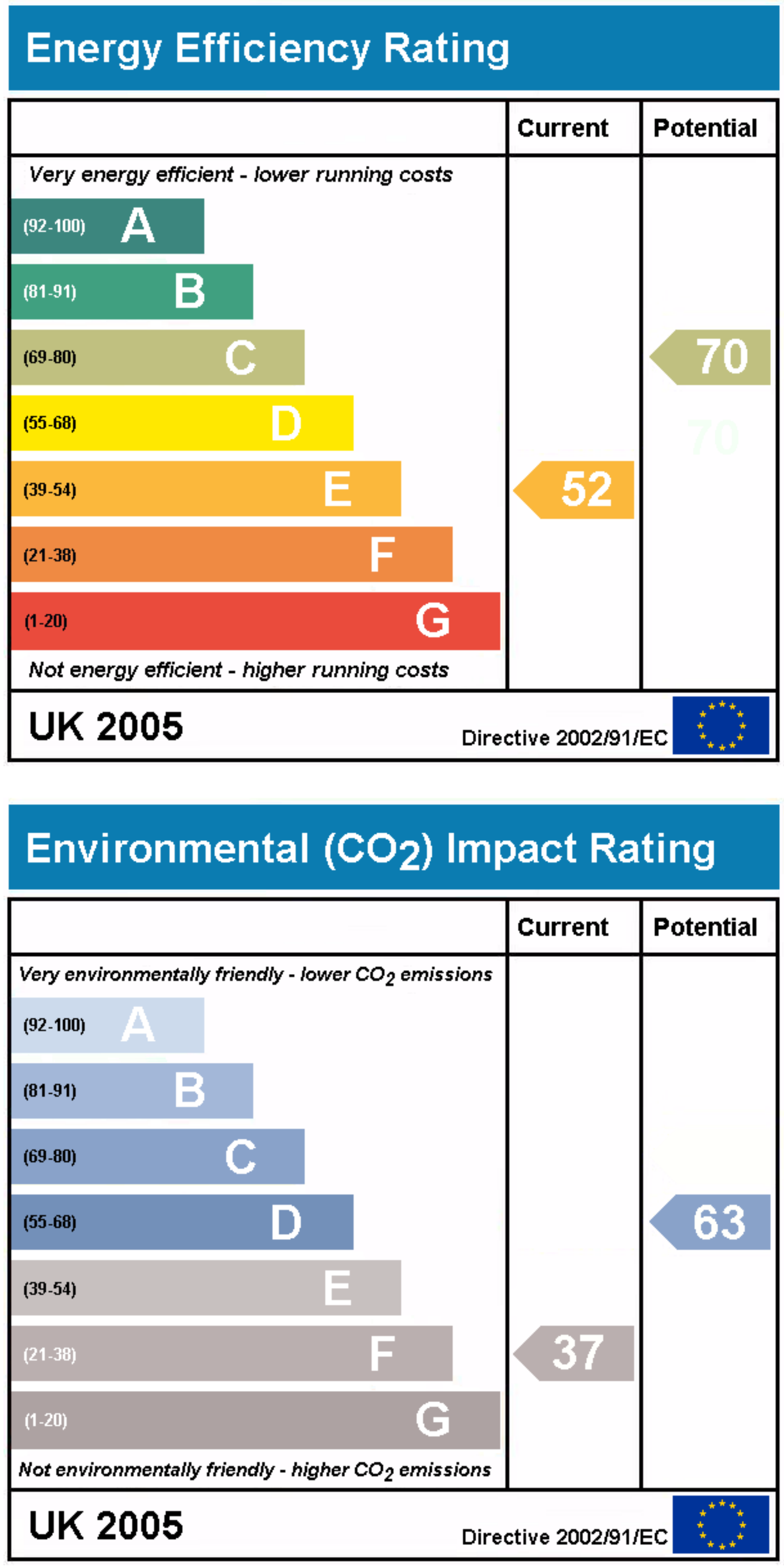


Figure 25 - EPC ratings

EPC is widely used across countries in the EU, UK, and other parts of the world for various purposes, especially when a house is bought. EPC is also part of a set assessment done periodically for all buildings in some cities. The evaluation includes more detailed data about energy use, house equipment health, potential upgrades needed, potential energy reductions, the potential for renewables, and more. The city of Milan has made its EPC data open source[50], and the UK has good tools[51] for anyone to check their home's rating. The UK also offers citizens to opt-out of their data to be public.

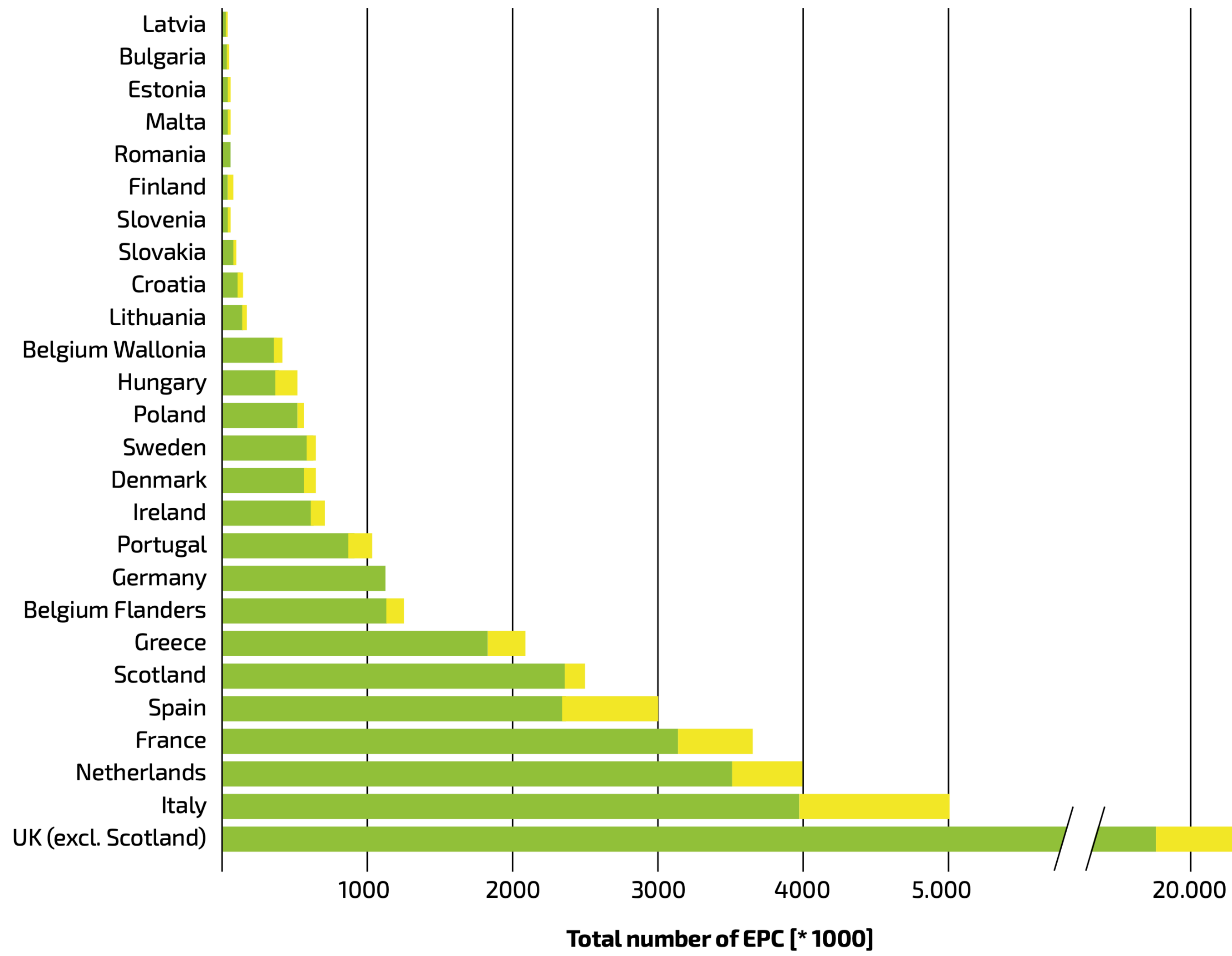
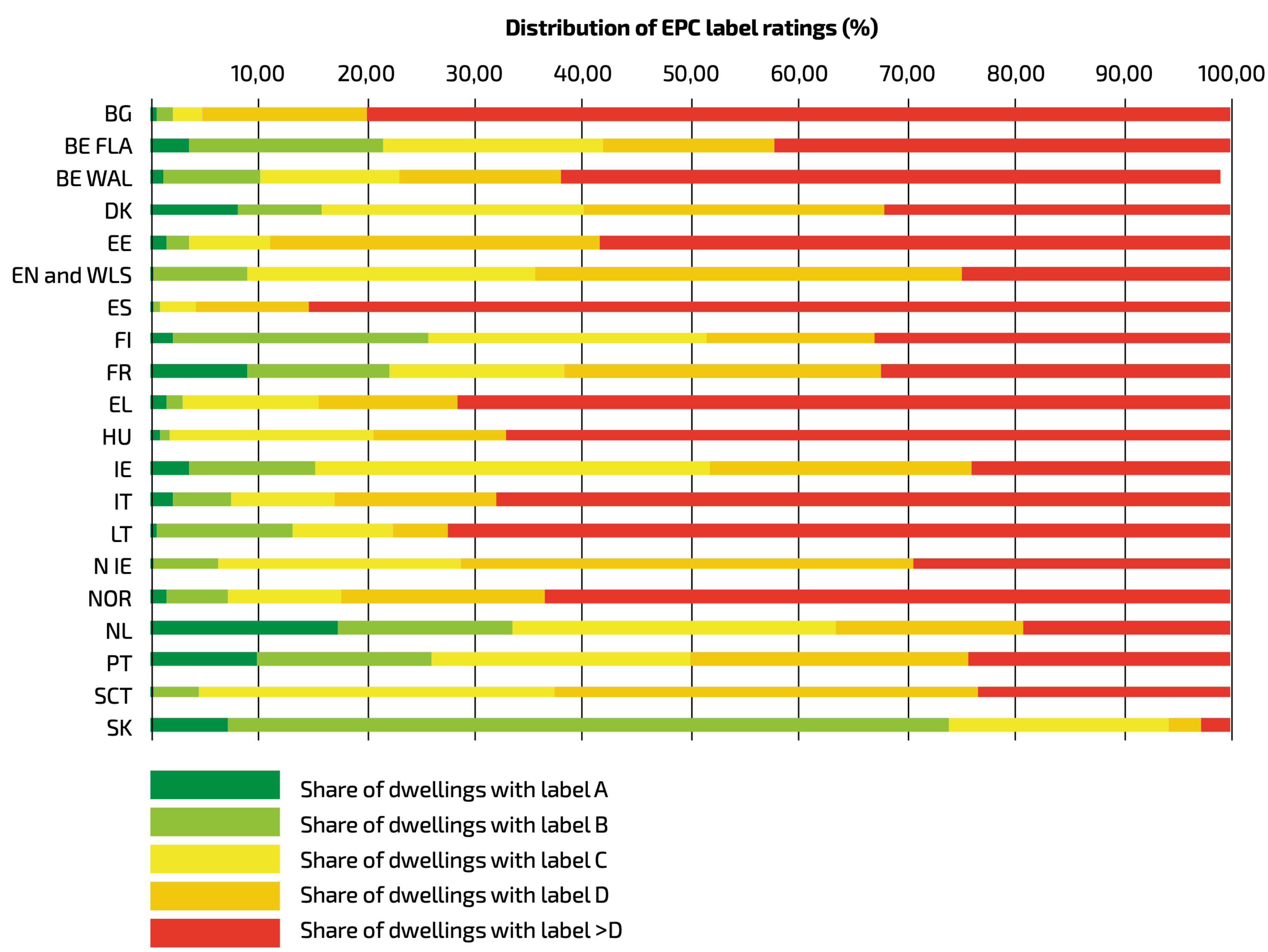


Figure 26 and 27 - Taken from Energy Performance Certificates Assessing their Status and Potential[52]



From looking into open EPC data in Milan, it is clear that it is done inconsistently. There are a lot of errors, empty values, lack full standardisation, shorthand text and mistakes. Some of these issues are the result of human data entry to paper and then later converted to digital protocols. EPC data does not tell the full picture of the building and community either. There is only focus on material and efficiency and not social and people metrics.

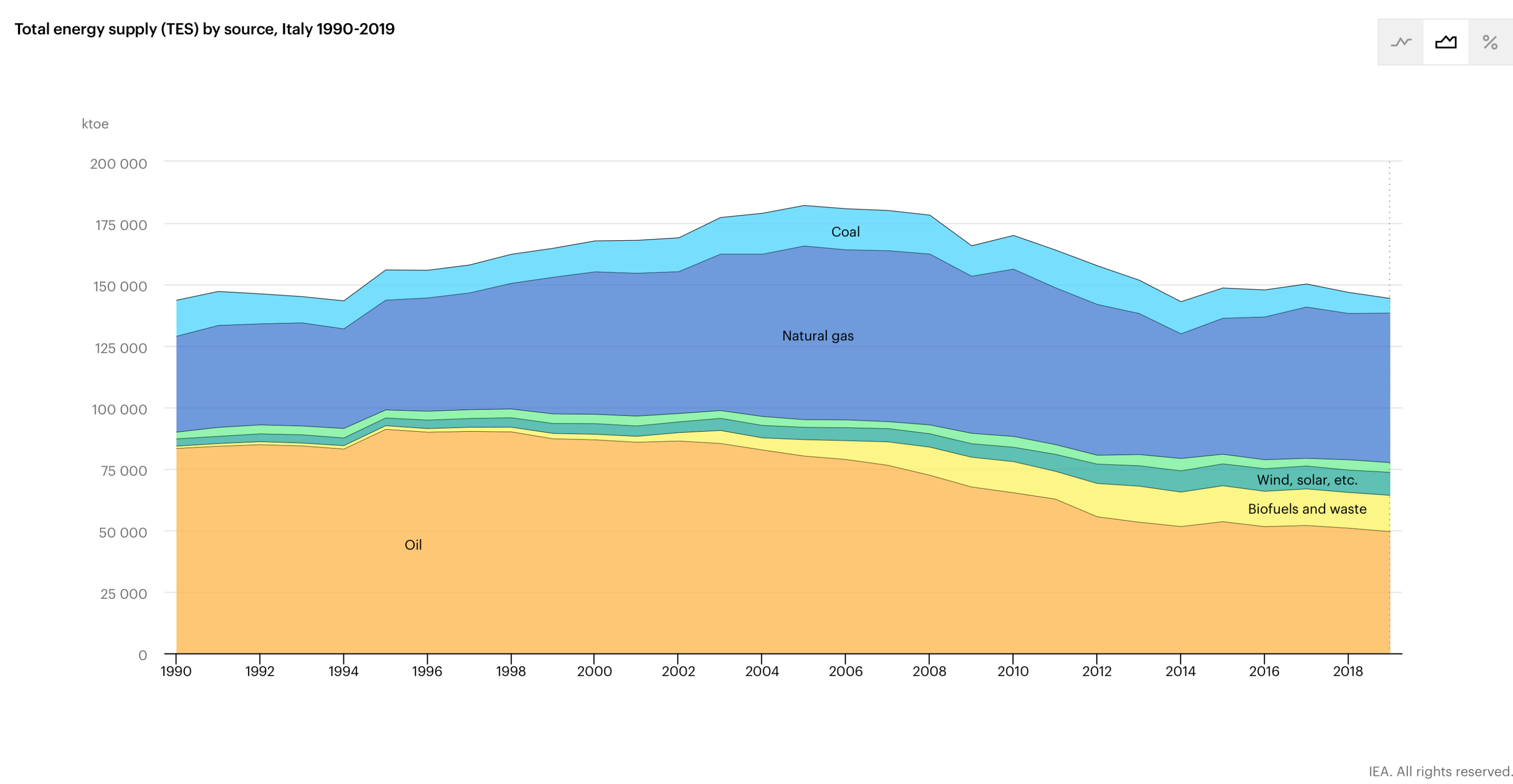


Figure 28 - Total energy supply sources in Italy, taken from IEA[53]

Net-zero energy building(nZEB): Concept of zero energy building. There are various standards like Passivhaus for the purpose, but different approaches and standards are being used in other cities. There is a lack of clear understanding of the term, how to do carbon accounting, and the team's certifications and skills to execute.

BIM: Building information modelling, made famous by Autodesk, is a tool for architects to create 3D models of buildings and can encode more data and information as layers.

House schema[54]: Open source initiative to create a schema and model for the home and built environment.

3.3.2 Primary data points

- Total energy use
- Heating energy demand
- Cooling energy demand
- Electricity use by appliances
- Renewable energy produced
- Home fabric
- Home internal environment
- Home materials
- Neighbourhood and community metics
- Retrofit measures
- Socio-economic data of area

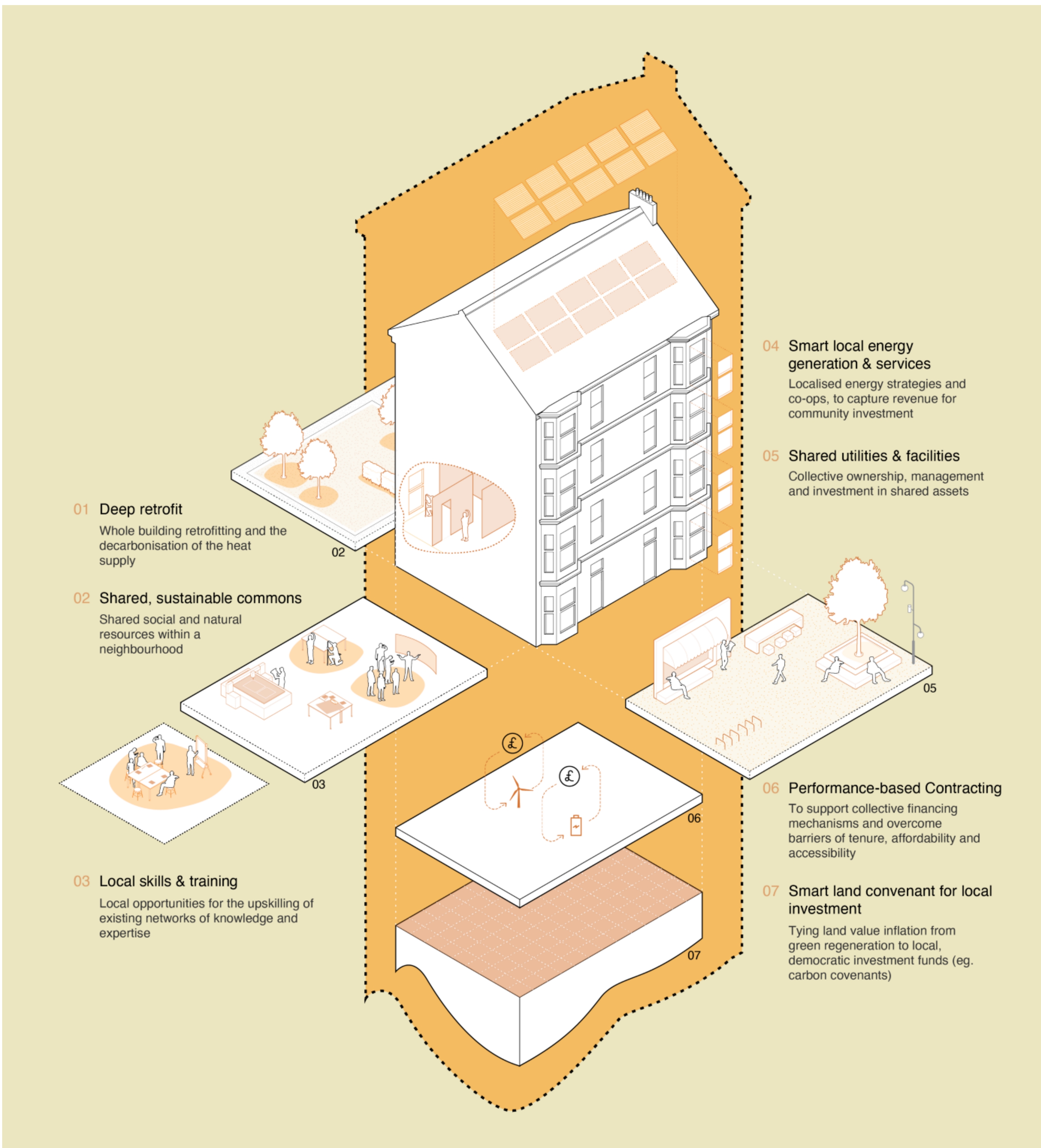


Figure 29 - Understanding retrofit as a whole system of recovery, created by Dark Matter Labs [55]

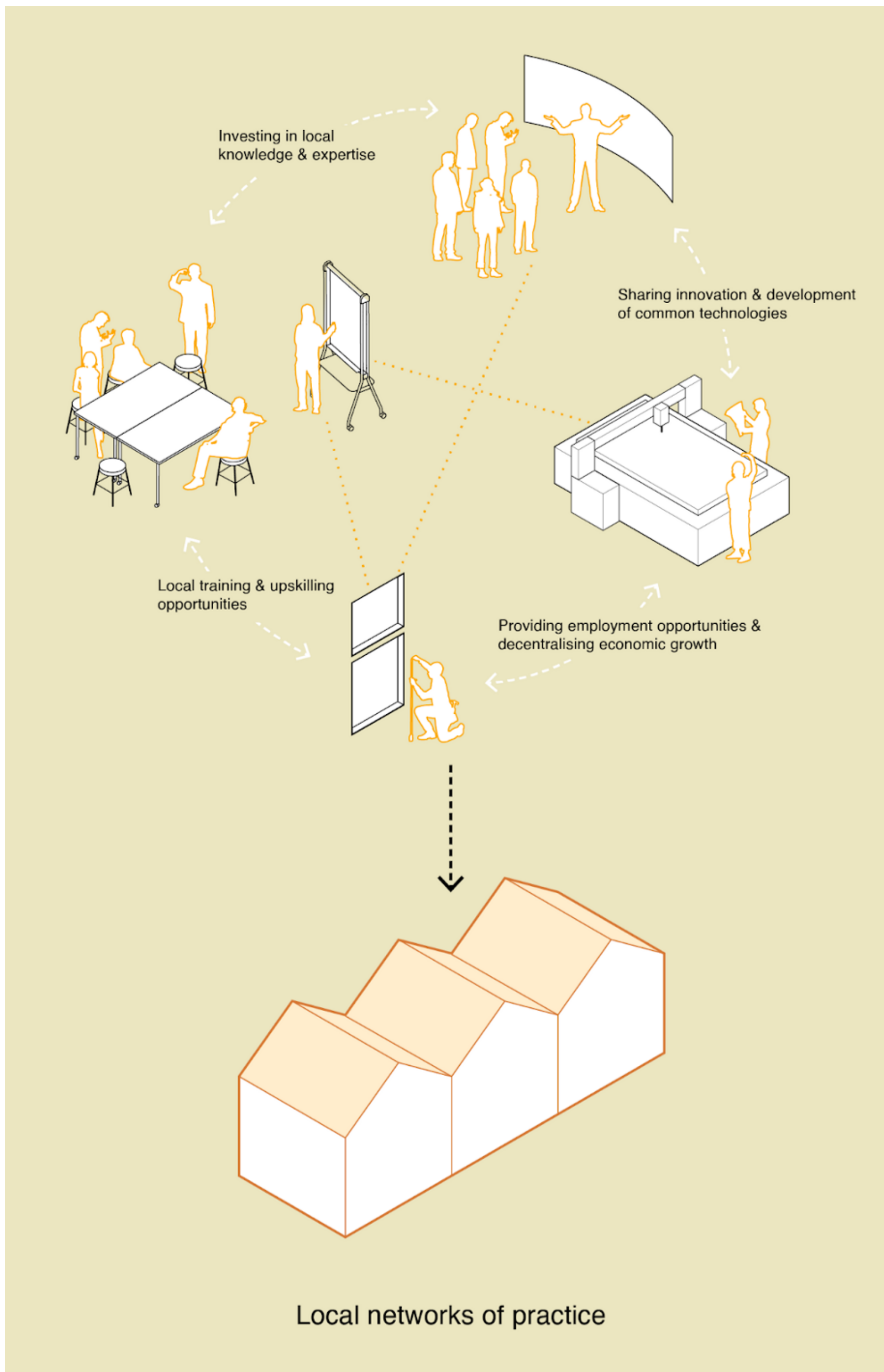


Figure 30 - Local networks of practice, created by Dark Matter Labs [56]

Open knowledge infrastructure

Building this open knowledge infrastructure serves as an evidence-base for new infrastructures, new standards, new legal patterns, or new institutions

Figure 31- Open knowledge infrastructure, created by Dark Matter Labs [57]

3.3.3 Monitoring and impact framework being developed in the project

1. Start by forming a community trust. Residents come together, create a decision-making community, get access to a shared bank account, and reach out to the whole community when needed.

2. Understand existing data and landscape. Form patterns of common trends among neighbourhoods and homes.

3. Create a local working network with training programs and community initiatives to come together and understand what a retrofit of their area entails. Use city funds to create procurements of people and partners who will do a detailed assessment of homes and perform needed work.

4. Create data infrastructure using sensors, smart meters, and resident reporting. Create dashboards for people to understand this data in a meaningful way, make connections with their built environment and historical context and understand individual homes vs. community metrics better. The focus should not be just on energy and carbon, but more meaningful data must be shown.

5. Create shared community assets and infrastructure, combined with added nature assets and urban trees.

6. Constantly monitor data and make retrofitting a regular process. Try to understand data anomalies and patterns.

7. Monitoring data can also be used to train AI models and make energy demand forecasting.

3.3.4 Financial framework being developed in the project

1. Retrofitting over a long period leads to money savings for both residents and energy providers. This amount can be calculated and used as capital needed for construction work needed.

2. Shared community bank accounts with transparent and democratic accounting can be used to maintain community assets and create events.

3. Positive climate impact made from whole retrofit and improved homes to be accounted and generate another source of revenues through carbon crediting or cryptocurrency token means.

3.3.5 Experiments conducted in the project

Several interviews, online surveys, and workshops were conducted with residents, city councils, and universities. Different cities have different challenges and progress levels. It is essential to collaborate with existing local solutions and create partnerships. There was a collaboration with Carbon Co-op[58] and Energiesporng[59], who have already been working in this domain.

The status of government and politics must be checked for the given context. Corruption, energy poverty, and lack of renewable energy can make project success very difficult.

1. Create information portals in different mediums and share them with residents of the community
2. Check awareness of retrofit funds for residents
3. Give residents able access to what benefits retrofit brings them and their community. Stressing on how much community retrofits have much more impact
4. Give residents the ability to express internet and consent
5. Form resident communities and kick-off project

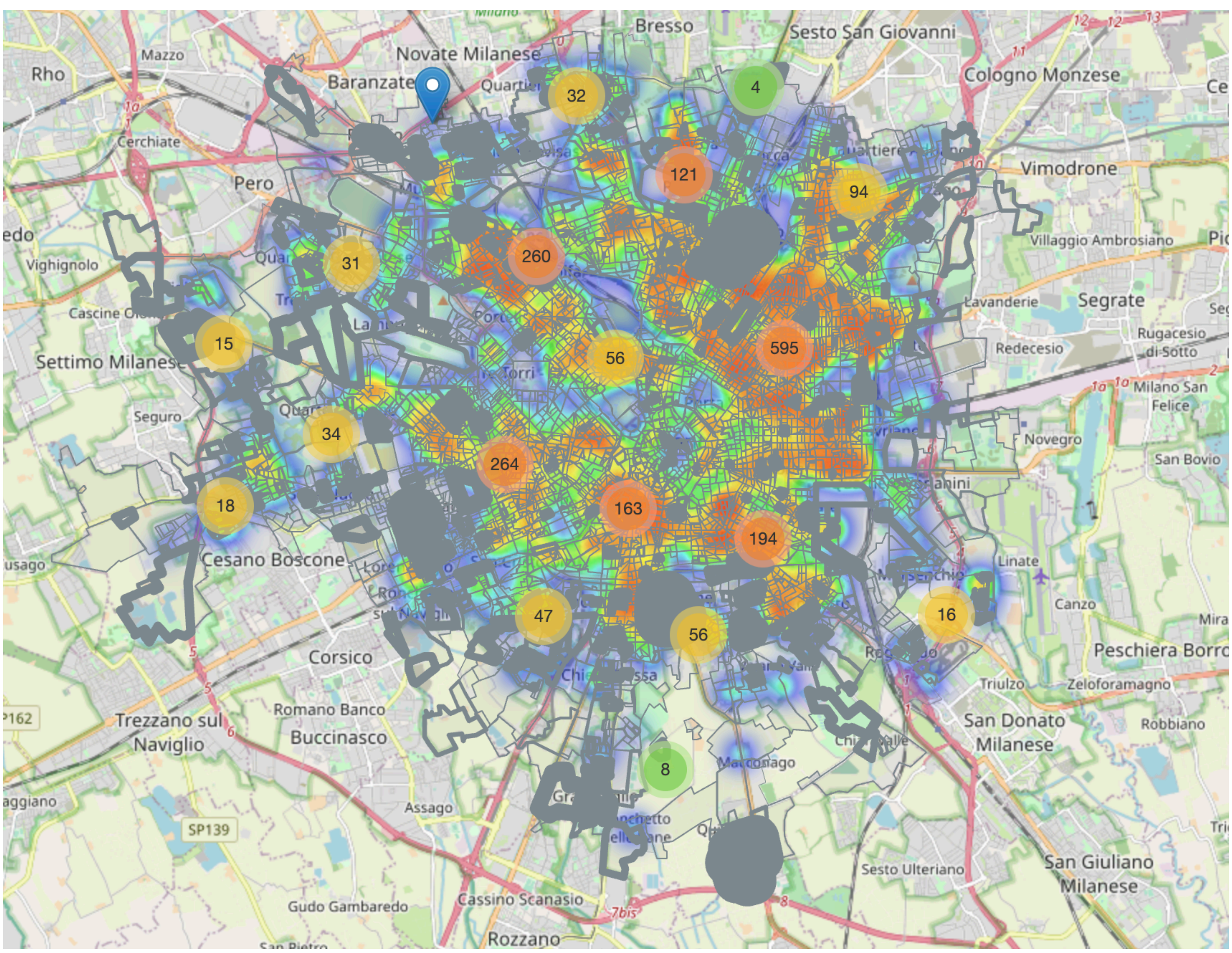
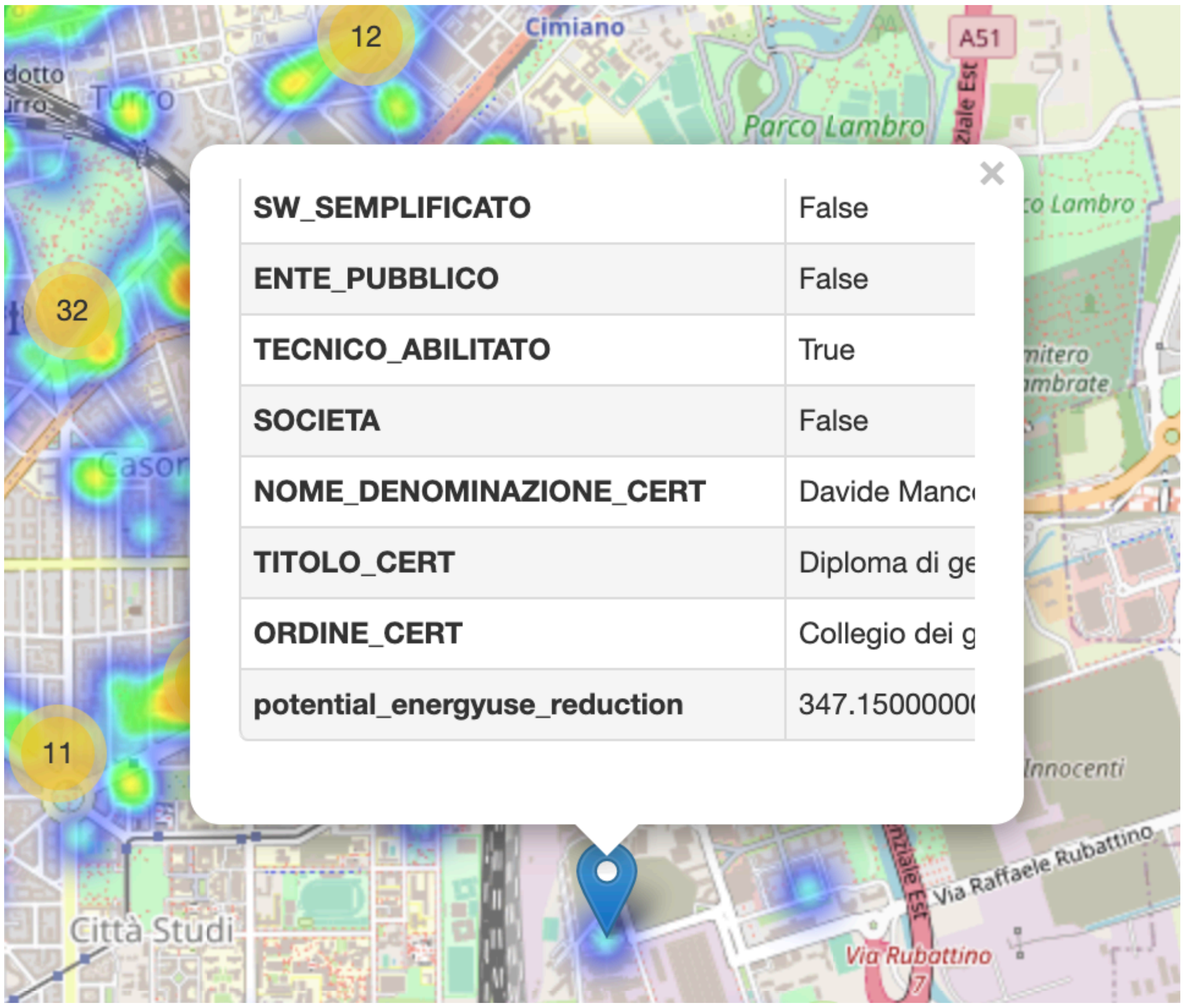
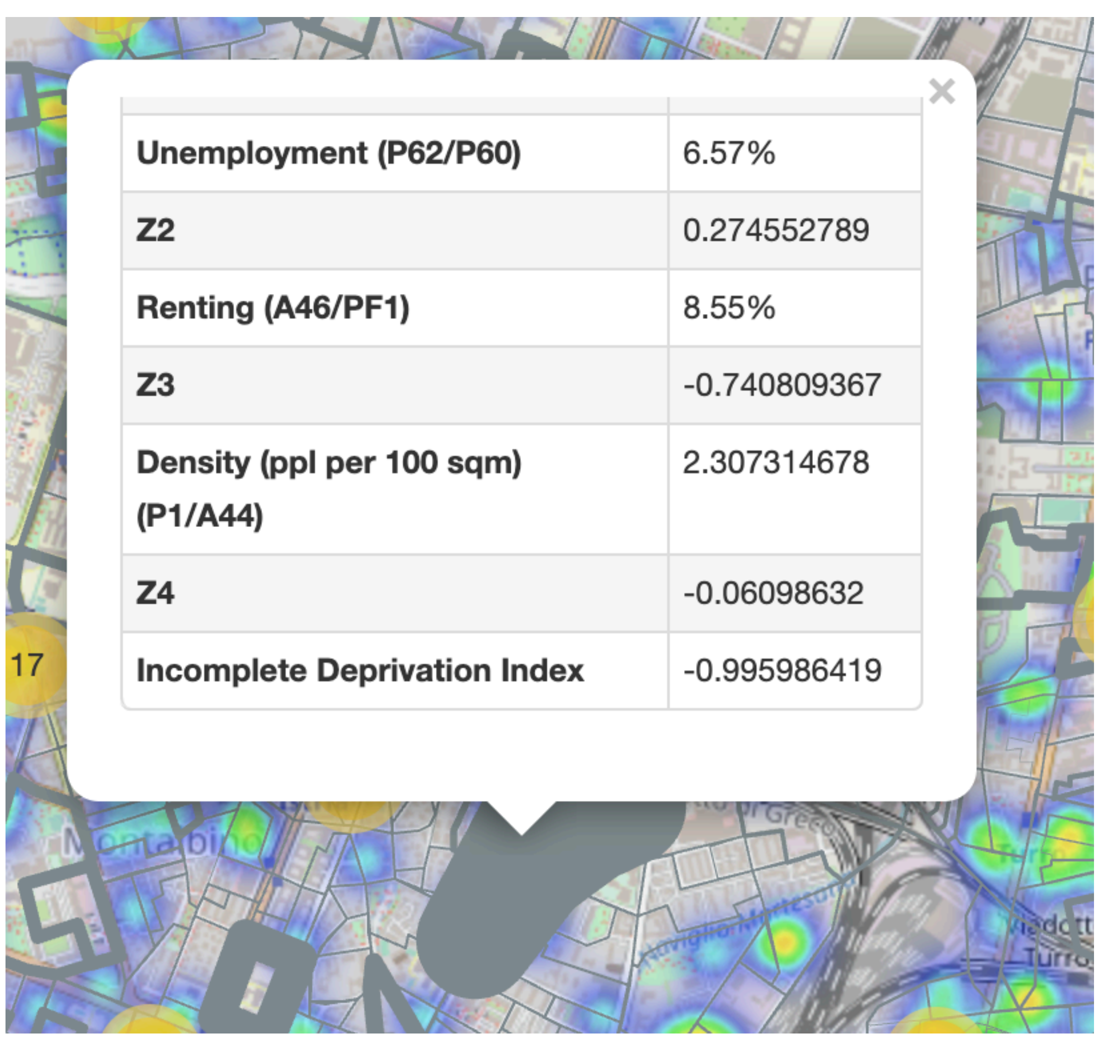


Figure 32, 33 and 34 - Milan EPC and socio-economic data visualised as a heat map to find patterns, done by the author[60]





3.3.6 Project status

The project was an early phase exploration of the topic. Reports have been created of all work and have been submitted. There is ongoing research into topics that emerged from the project- Spatial Justice and Embodied Carbon of material. A blog series was posted in April 2021[61].

3.4 HOW ARE GAPS AND PROBLEMS BEING ADDRESSED?

3.4.1 Co-design with cities

All project work always involves working directly with cities and co-designing the project. Dark Matter Labs does not work in consultant fashion; instead, it works to create capacity, knowledge, and needed work culture in city councils to develop, foster, and maintain the digital infrastructure on their own. There is also a constant check that dynamics are not top-down but rather citizen, nature, and the environment first. And there is continuous work to keep informing the city and citizens of the dangers of technology and how to account for them.

3.4.2 Community building

Change cannot propagate with the top-down models or just expected to be done by governments or corporations alone. All these ideas need to be community-led and with public-private relations. There will be no one-size fit all model to do this, and every country will need its approach. Yet cities and governments need to come together as a network. Community building is first required to spread awareness and shared understanding, co-design how to work, perform collective decision making, form working groups and bodies to represent local neighbours working in collaboration with needed contractors and governments. Thus the required changes come collectively. And also, there is a need to zoom out to a planetary level, not just stay forced on country measures. Everyone has to work on the climate crisis as one planet and not the scattered effects of different countries with misaligned goals.

One goal is to develop physical lab spaces in neighbourhoods to come together to understand data and initiatives, rewards, and citizen sensing activities. An aspect of the legal entity must also be created to have shared bank assets, risk mitigation, and other vital steps needed. Different strategies for those in rural Global South without basic amenities need to be developed and how funds can be allotted for their upliftment based on predicted future financial models. Levels of corruption, uncertainty, and unfair actors in the system need to be accounted for instead of having a blind eye. Systems need to be built with resilience.

Also important to note all the different ways technology is being used for digital community building through prevalent apps like TikTok and Instagram. Or private chat clients being used to organise. These centralised mediums' main goal is to profit from content and are often found policing the content. Hence a change is needed here.

3.4.3 Data justice

There is a constant check on potential harms data collection and assertions can do. And efforts to keep citizens informed, get their consent with complete transparency, and make all algorithms, code, and models open source.

Design Justice Network Principles, taken from Design Justice Network[18]-

Principle 1: We use design to sustain, heal, and empower our communities, as well as to seek liberation from exploitative and oppressive systems.

Principle 2: We centre the voices of those who are directly impacted by the outcomes of the design process.

Principle 3: We prioritise design's impact on the community over the intentions of the designer.

Principle 4: We view change as emergent from an accountable, accessible, and collaborative process, rather than as a point at the end of a process.

Principle 5: We see the role of the designer as a facilitator rather than an expert.

Principle 6: We believe that everyone is an expert based on their own lived experience, and that we all have unique and brilliant contributions to bring to a design process.

Principle 7: We share design knowledge and tools with our communities.

Principle 8: We work towards sustainable, community-led and -controlled outcomes.

Principle 9: We work towards non-exploitative solutions that reconnect us to the earth and to each other.

Principle 10: Before seeking new design solutions, we look for what is already working at the community level. We honour and uplift traditional, indigenous, and local knowledge and practices.

Data labour

Under prevalent business models, data creation is often not fairly rewarded. Rewards come under app-created metrics like Likes/Favourites and app controlled interlinked and hidden promotion mechanisms on which lots of people's livelihood depends. This is linked with design strategies of addiction and negative patterns. Often what is ignored is data labour behind the data creation.

People's data is sold to advertisers where the company earns big profits. This is highly targeted data, having a full interest spectrum and needs of the people. These models need to be challenged, and data creation must be fairly compensated.

Data strategies

Many strategies can be used to help aid these concerns with data and privacy. Like randomised responses[62], building with citizens, non-extractive business models, keeping the project open source, performing regular audits, and having bug bounty programs.

Data ownership

In current technology models, data still needs to be owned by a central authority willing to pay the data centre and services bills. But there is ongoing research and following decentralised co-ownership and peer-to-peer models enabled by DLTs.

3.4.4 Material registry

Dark Matter Labs is working on a concept called Material Registry, which will explain the embodied carbon of any given object with a complete life cycle involved. From raw material extraction to production, usage continued impact and death cycle. This concept is quite a challenge to create and is in the early conception phase. The goal is to show numbers and tell an entire story that can be easily understood and trusted by people.

3.4.5 Outcomes based approach

There is work to create and define outcome-based terminology in projects. Outcomes mean not thinking in singular metrics or KPIs but assessing combined entanglements through outcomes. Outcomes are first made from a monitoring perspective, deciding how to combine holistic data metrics to create understandable outcomes. In financing mechanisms also it is easier for beneficiaries to fund outcomes.

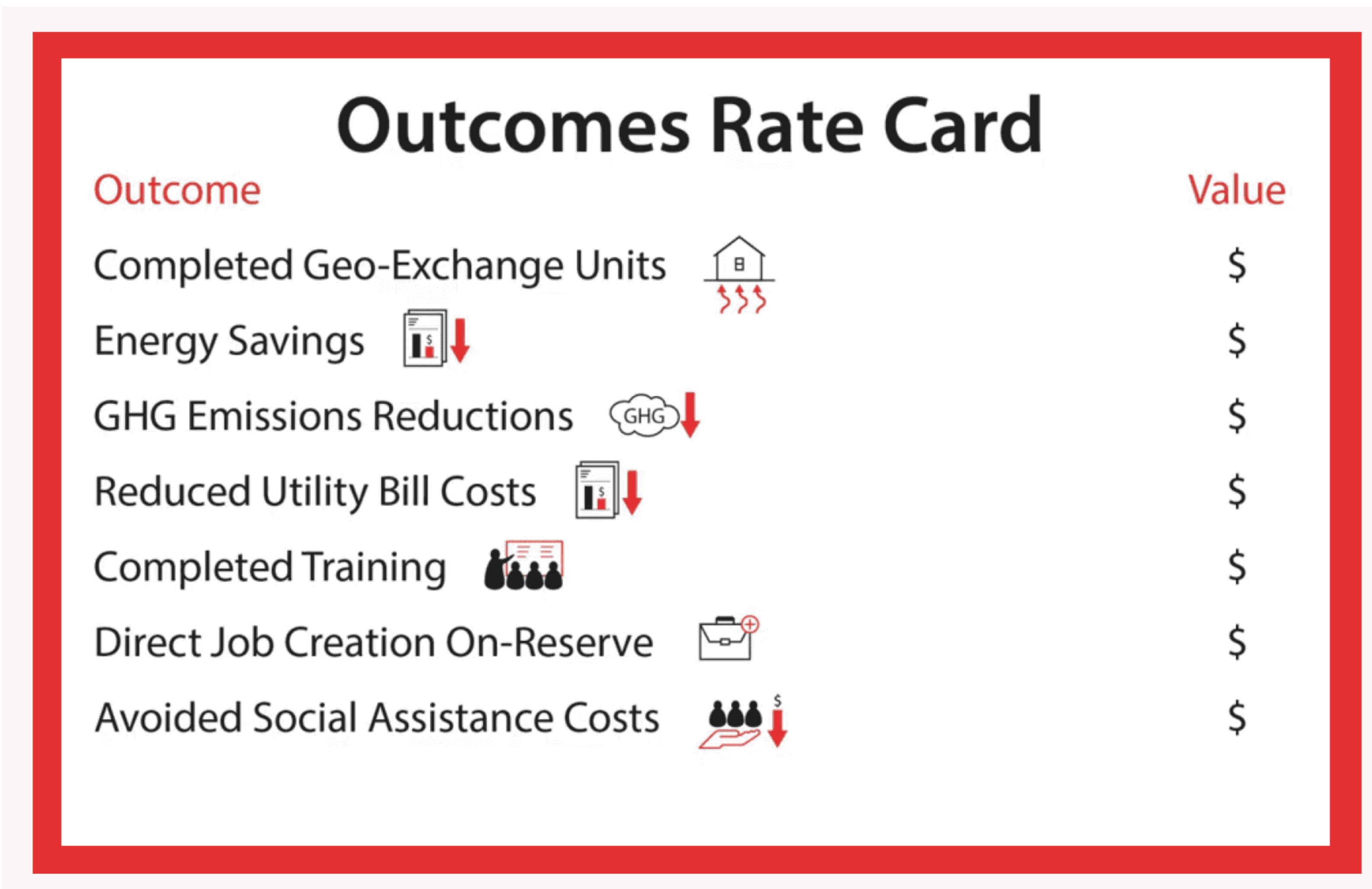


Figure 35 - Outcomes report card taken from Community-Driven Outcomes Contracts[63]

4. GUIDELINES FOR HOLISTIC USE OF CLIMATE TECH

As a result of all research and project work, a set of guidelines is created by the author to guide and improve the use of climate tech while being able to work on its challenges and access tech maternity and data justice for a given project.

4.1 PRINCIPLES

4.1.1 Assumptions

Project goals and intentions need to be first established, both in the short term and long term. This guideline does not focus on project setup or the overall work process. Instead gives essential points to integrate tech materiality and data justice into work that can be otherwise easily overlooked.

4.1.2 Not just technology but technology with social issues

There is a myth that tech is politically neutral. And often, regulation fails to catch up to technology, which has led to the issues mentioned before. Thus as we advance, tech and social issues cannot be separated. Accessibility, the global divide, and poverty must be brought to the table if technology is to be a public good.

4.1.3 Self critical checks along the way

It is essential to be self-critical at each step of the project and keep testing and validating assumptions. Often, there is a bias toward one's idea, which leads people to keep pushing it. Self-criticality also means to stop and check what intentional and unintentional impact is happening, address it and make the needed changes. And also being able to access the root cause of the issue at hand.

4.1.4 Citizen lead and not user lead

Climate tech should not go through the same issues which are in consumer tech. Extractive business models need to change and be challenged. The sense of selling products to users needs to be transitioned to co-designing services with citizens with community meetings, complete transparency, capacity building, and appointing positions where needed with ample compensation for data labour.

4.1.5 Nature benefiting not just human benefiting systems

Most systems created by humans have inherently been human-centric, which means humans are established as only beneficiaries of the system. Decisions are taken to maximise human profiting metrics like income increases. This has altered our relationship with nature and biodiversity and established nature as a 'resource' used for human benefit. There is a need to challenge this relationship and transition our systems to be nature and biodiversity-oriented, making decisions just for benefitting nature objectively. If nature prospers, humans are beneficiaries as well.

4.2 CORE TOPICS

4.2.1 Green Algorithms

Green Algorithms is an ongoing open-source project was developed at Cambridge University [64]. The goal to establish a standard and best practices to use technology in the most energy-efficient way possible. The project shows emissions created by taking in details of the algorithm and cloud deployment. But it is a small project and needs a lot of work, attention, and effort. Such projects need prominent consensus in the community and trust in the values it reports. And then regulation, standards, and protocols ensure its usage in climate tech projects to account for tech materiality accurately.

Such emissions accounting only shows the partial picture. To account for the full spectrum of tech materiality, there needs to be the inclusion of the entire life cycle of all the material required to produce the large-scale tech infrastructure, all mining and labor that enables the extraction of the material, its life cycle, and death cycle. How to make sure there is reusability and repair, and acknowledge which materials are not recyclable and accumulate as waste. Lastly, emissions accounting should also include the network of consumer applications on which the climate tech solution relies.

Location and type of data centre can also make a big difference. There is a lot of work developing algorithm techniques to minimise emissions, but it is the coder's responsibility to stay updated and optimised code where possible. And transparently account for all created emissions.

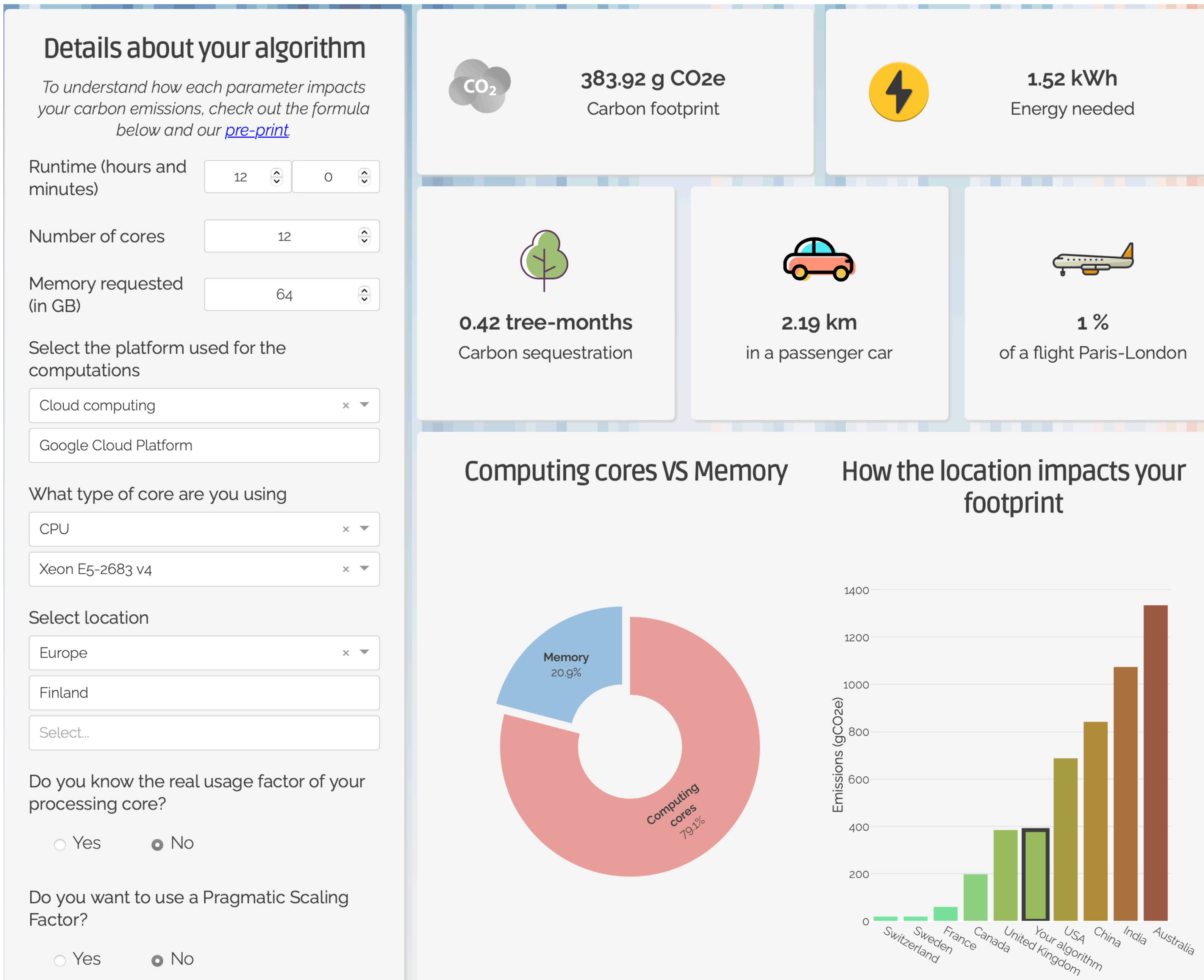


Figure 36 - Screenshot of Green Algorithms interface[64]

1. Carbon: Build applications that are carbon efficient.
2. Electricity: Build applications that are energy efficient.
3. Carbon Intensity: Consume electricity with the lowest carbon intensity.
4. Embodied Carbon: Build applications that are hardware efficient.
5. Energy Proportionality: Maximize the energy efficiency of hardware.
6. Networking: Reduce the amount of data and distance it must travel across the network.
7. Demand Shaping: Build carbon-aware applications.
8. Measurement & Optimization: Focus on step-by-step optimizations that increase the overall carbon efficiency.

Figure 37 - Summary of Principles of Green Software Engineering[65]

4.2.2 Tech terminology

Terminology is fundamental; it informs how we think and associate with a given object or process. Most of the terminology used in tech came from industrial practices and made for marketing purposes. First, we need ecological terminology in general and a specification of an eco terminology for tech. New technical terminology needs to be developed to change the perception of technology. Created with nature-based terms and easily understandable and truly representing the materiality of technology.

Tech features terminology such as 'disruption,' 'cloud,' 'master-server,' 'server-less,' etc. Business models which aim at disrupting society and not treating it with a care need to be challenged. Cloud and server-less have become standard terms for data centres and heavy energy infrastructure. Such terms abstract away the materiality and present as light and invisible. Terminology drives intention.

Figure 38 - Field Guide for More-than-Human Politics[66]

There is many going work to develop ecology based lexicons such as *Towards an ecocentric lexicon*[67] and *An Ecotopian Lexicon*[68]. Connections of such ongoing works must be made with technology.

4.2.3 Indigenous protocol guidelines

As part of the published position paper *Indigenous Protocol and Artificial Intelligence*[69], there are established Guidelines for Indigenous-centred AI Design v.1 which must be ingrained into climate tech. The guidelines are-

1. Locality
2. Relationality and Reciprocity
3. Responsibility, Relevance and Accountability
4. Develop Governance Guidelines from Indigenous Protocols
5. Recognise the Cultural Nature of all Computational Technology
6. Apply Ethical Design to the Extended Stack
7. Respect and Support Data Sovereignty

The paper also gives a very useful guide for conducting workshops, usage of art and storytelling, and not just keeping indigenous values in the theory of the project but also bringing into the practical implementation of tech.

Figure 39 - How to Build Anything Ethically taken from Indigenous Protocol and Artificial Intelligence[69]

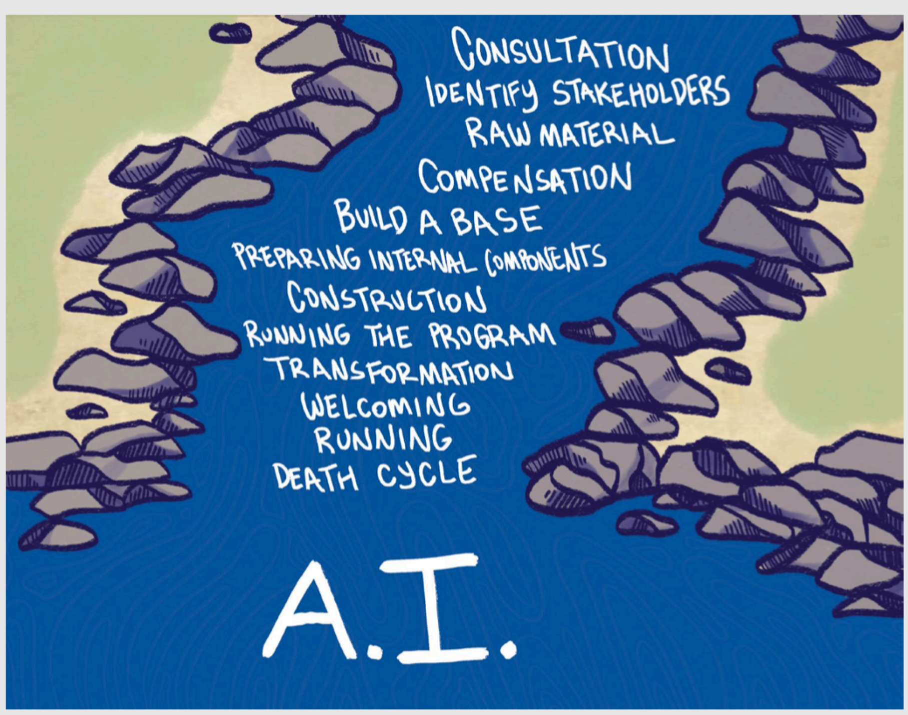
HOW TO BUILD A SWEAT LODGE IN A GOOD WAY	HOW TO BUILD A PHYSICAL COMPUTING DEVICE IN A GOOD WAY
APPRENTICING	
When building a sweat lodge in a Good Way, first, one acts as a Fire Keeper for someone else. My grandfather learned from an elder Medicine Man, and started Sundancing with him. When a person does Sundance they are preparing constantly during everyday life and doing sweats all the time. This a slow process of learning from the elders and community members about the correct way to do things. Before a person can start their own practice, they must have a vision where the spirits call them to build their own *hamblecha*, or altar, otherwise they continue to assist others.	Building (in a Good Way) a physical computing device to house an AI would first require study and consultation with a committee of knowledge keepers with expertise in computation, ethics, and mining.
IDENTIFYING NEED	
Before you build a sweat lodge, there must be a need: you, your family, and the community needs purification, a place to pray, a place to do ceremony, a place to do medicine, and a place where individual and communal needs can be addressed.	Why is a physical computing device needed? In this example, it is to host an Artificial Intelligence program in a physical object created in a Good Way.
IDENTIFY STAKEHOLDERS	
The stakeholders in a sweat lodge are many, but the lodge has room for all individuals and community members, known and unknown, seen and unseen, including: • Stone Spirits • Plant Peoples • Animal Peoples	The stakeholders in a computational device are: • the communities of the location where raw materials originate • the raw materials themselves • the environment around them • the communities affected by transportation and devices built for transportation • the communities with the knowledge to build these objects

• Human Peoples • Spirits • Guardian Spirits	• the communities who build the objects • the communities who will use and be affected by their use • the creators of the objects
IDENTIFYING RAW MATERIALS	
The sweat lodge is built from/with raw materials: willows, rocks, tobacco, cloth, buffalo hide. These are multiple items, each with their own protocol streams, with similar protocols for each of the materials. Each has to be done with protocol, in a Good Way, offering something valuable in exchange for taking something of value. There are many kinds of exchange in Lakota culture. These exchanges range from reciprocity to radical gift-giving to bribery to offering, all of which signify an ongoing relationship. This may seem like extreme gift-giving when one offers their flesh, their hair, or every material object they own. However, this protocol is modelled after the animals which give themselves out of responsibility, upholding long-running agreements to care for us. When you collect the sixteen willows for the sweat lodge, you must offer tobacco. You must offer tobacco when you take anything, even filling the water. If you don't have tobacco, you can offer a piece of hair. When obtaining the buffalo hide, it is important to consider the way the buffalo is killed and skinned, ensuring that the ceremony was conducted in a Good Way and the buffalo's spirit is released in a Good Way.	Extracting materials in a Good Way requires transparency, regulation, and research into developing physical computing devices which do not use a single new material and eventually do not require mined materials at all. The refining of many elements which are mined (rocks, metals, minerals, etc.) produces toxic and non-recyclable waste.[4] What is being offered to the Earth when we extract these mined materials? What is being offered to those whose lands are being extracted from? For our human kin, we can start with fair wages.[5] For our nonhuman kin, it is the repair of the earth back to a healthy state. Funds must be diverted to research alternatives and to manage ongoing environmental destruction.

CONSTRUCTING	
A prayer is made each time the willow poles are crossed and tied together with specific color cloths. An eight-pointed star is revealed at the top. Melita Stover Janis says, "They [the spirits] come in through the top [of the lodge], as the singers sing the first songs, calling the spirits into the sweat, a portal from one world to the next." When assembling the lodge, you must pray to each direction, hanging the appropriately colored offering in each door. Scott Benesiinaabandan says, "This arrangement is meaningful, there are four levels above and four levels reflected underneath the earth, creating a sphere."	The arrangement of the internal components of a physical computing device is functional, as is the arrangement of the willow poles. However, Indigenous design practices unite functional design with functional symbolism, a method which can be extended to the design of circuitry, inviting the spirits in as well as again offering tobacco each step of the way.
PREPARING THE INTERNAL COMPONENTS	
Another stream of protocol guides the building of the fire which heats the lodge stones. This fire has specially appointed Fire Keepers, who gather firewood, set the fire up, and lay the sticks across. The Fire Keeper must learn through apprenticeship and has a very important role.	Fire Keeper protocols could be translated to building and arranging the processor and the RAM, taking special care to prepare where the builder perceives the 'location' of the AI.

WAKING UP	
Inside the lodge, the singers ask that the spirits of the rocks help them, waking the spirits up with offerings of tobacco. Rocks are only added in meaningful numbers and groups. “Grandfathers live in the spirit world and come into the living, giving their lives. Singers inside [the sweat] wake them up,” says Scott Benesiinaabandan.	Functionality and symbolism in the design allow for the singers to call in the spirits to help them, similar to the programmer calling the code to begin running a software program.
ALGORITHM	
Songs are the action in a sweat lodge, doing the most vital and complex work. These songs involve many kinds of algorithms: the Lakota language and its complexities of purpose and meaning, the arrangement of the song’s poetry, the choice and order of song by the leaders, and the patterns of the air waves being formed and reformed by the melodies and harmonies of the participants’ voices.	The arrangement in the writing of the software, the algorithms and code structures which work together in intricate ways must also be designed in a Good Way, combining all the parts to make the whole: from training sets to interfaces.
TRANSFORMATION	
When all the parts of sweat lodge are brought together in a Good Way, transformation occurs. Rocks, together with the fire, water, and air, create steam. The stones (known as Grandmothers and Grandfathers) are offered tobacco along with songs asking for their help and assistance. Water becomes steam, rocks become dirt, willow becomes ash, tobacco becomes sparks: transformation is the most important part of these ceremonies.	Using electricity, energy, the correct arrangement of materials into motherboards and all parts of the physical computer device, current flows, transforming into semiotic information, rendering it sensible to humans. It is through these transformations that what we will perceive as AI could be found.

ANNOUNCEMENT	
When objects with spirits are made they must be feasted, meaning a feast must be prepared in honor of that spirit. Dried meat (wasna), choke cherry juice, and ceremony feasts are offered.	The computer should be announced to the community of stakeholders and named. This step is essential to building this object in a Good Way, with clarity and transparency to what has been built and why. In order to live in context, this object must have clear relationships to its stakeholders.
DEATH CYCLE	
Sweat lodges can be disassembled, repurposed, returned, or transformed. When the season for sweat lodge is over, you take the covers off, leaving the lodge if it will be used again. The sweat rocks eventually break apart, disintegrate as they are used. Everything is organic and can be reused, burned, or returned to the earth.	A physical computing device, created in a Good Way, must be designed for the Right to Repair, as well as to recycle, transform, and reuse. The creators of any object are responsible for the effects of its creation, use, and its afterlife, caring for this physical computing device in life and in death.



4.2.4 Subtractive solutions

Adding is favoured over subtracting in problem-solving[70] states how there is a bias towards additive solutions - the inclination to add novel ideas and platforms to make improvements instead of removing existing layers. More funds are allocated towards additive solutions. Work is needed to develop and shift towards subtractive strategies and removing elements instead of adding new ones.

4.2.5 Low and small tech

Instead of always relying on the latest technology like AI and heavy-duty sensors, there should be maximised usage of low-technology solutions in the given context. Low technology is a term that is not clearly defined in the community and entails different types of low-cost and low materiality solutions. The paper *Nature Based Solutions for Urban Resilience: A Distinction Between No-Tech, Low-Tech and High-Tech Solutions*[71] states different tech solutions for NbS based on given characteristics and context of the project.

Focus on awareness and creation of small local co-ops for data centre and services provision, such as Sheffield-based co-op[72], to power cloud and cloud operations instead of relying on Big Tech cloud providers.

Wholegrain digital lists out these questions to consider for hosting provider[73]-

- Do they have any of their own renewable energy generation? For example, wind turbines or solar arrays.
- Do they have any direct energy supplies from other local renewable providers?
- Do they have energy contracts that specify renewable energy from the relevant countries' national grid?
- Are they buying renewable energy credits (RECs) and/or carbon offsets? If so, where are they buying them from and what do they actually mean?

Minimal computing[74] and Small Tech[75] are essential approaches towards solving some of the issues with tech.

4.2.6 Data trust

The concept of 'Data Trust' isn't clearly defined yet and can be interpreted differently by different scholars and research institutes. Open Data Institute's report[76] defines data trust as "a legal structure that provides independent stewardship of data". The goal is to create a legal and transparent body responsible for protecting data, how it is being used, and how different data sources get mixed. There are different pilots and research projects to explore various legal and governance structures to establish trusts while keeping the public good at the centre. ODI's report also gives protocols and activity to develop such trusts for the given context.

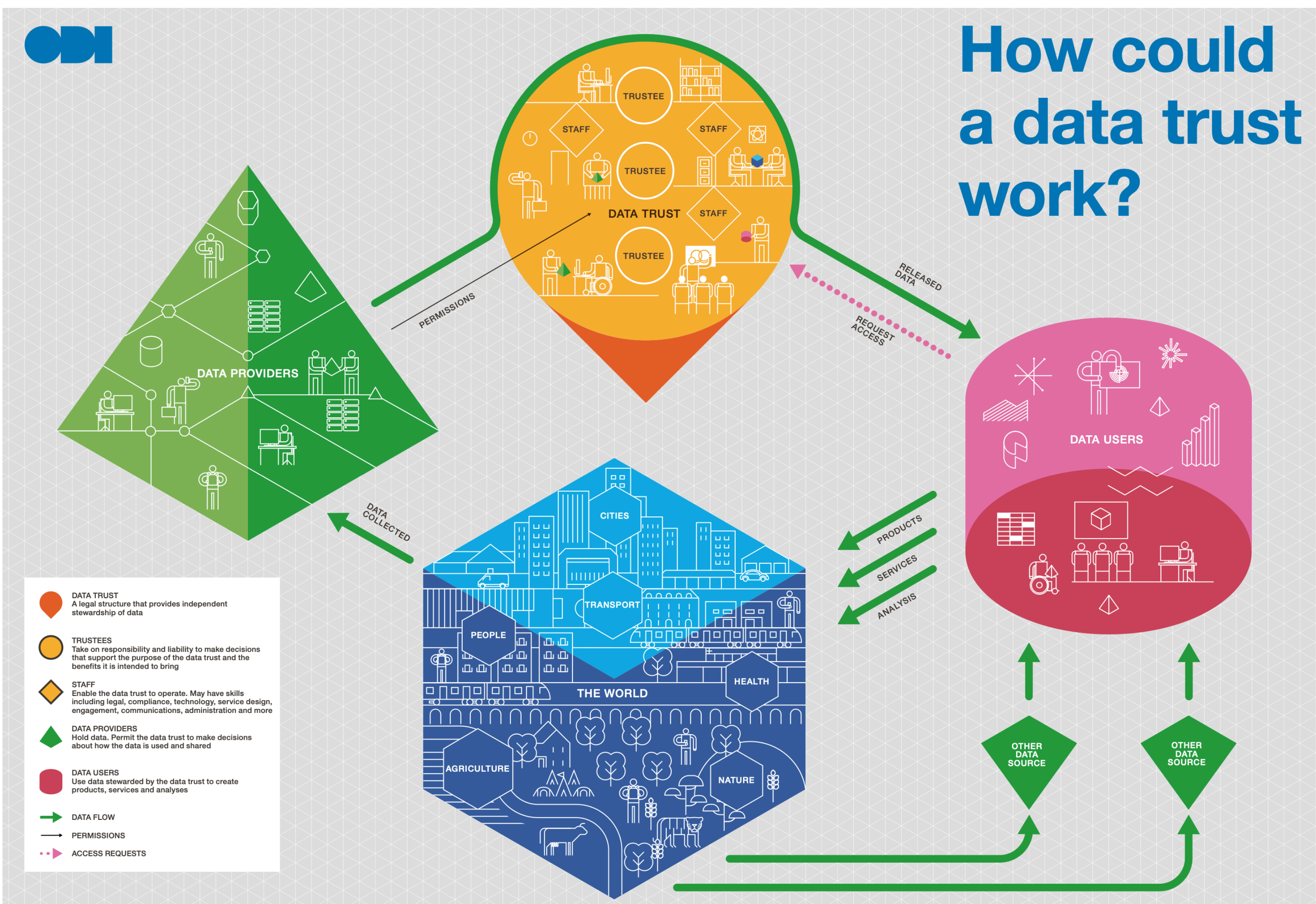


Figure 40 - How could a data trust work?[77]

4.2.7 Shared standardisation and connections

As mentioned before, there needs to be better development and maintenance of standards required in various places, with the idea of building solutions that can connect and integrate to work together and understand the impact of cumulative efforts. Not all data centres are the same - not all algorithms are the same. Shared learning and trustable standards are needed to move forward. Trust bodies need to be in place to formulate and keep maintaining such standards with the changing landscape of technology and new research coming in. Care has to be taken to make such protocols accessible and acknowledge both the Global South and North.

4.2.8 Carbon offsetting issues

Carbon footprint calculators have gained a lot of popularity in the last five years, where individuals can learn their carbon footprint based on data they input about their lifestyle[78]. But such calculators were created by the big oil company BP to shift climate responsibility on individual effort successfully. Reliance on such calculators must be reduced and make focused climate action efforts through individuals' community cooperation and institutional changes.

Another typical method tech's materiality and emissions are being addressed is carbon offsetting, which means the emitter pays funds to offset their emissions. But this is not a solution and still does not stop the needed emissions.

4.2.9 Solarpunk and speculative futures

An emerging genre in fiction writing is Solarpunk- a genre that explores what an ecological utopia could be like, through storytelling and different mediums of art. Storytelling combined with speculative design can be a beneficial tool for collective acknowledgement of the climate crisis and can imagine how a crisis-free future would be.

4.2.10 Long term changes needed

A long term and institutional change and shift is needed followed by regulation to make the required change for climate action-

- Changes in how often new technology is released. Currently, there is no control over this and every brand releases a new cycle of technology very often to maximise its profits
- Detangle and reduce the amount of tech consumerism. Marketing and consumptions patterns need to be acknowledged and transitioned towards reduction of consumption and elongating the life cycle of technology
- Make technology easily repairable, sharable, and replaceable

- Build more awareness of tech materiality and data justice
- Break down the monopoly of Big Tech
- Clear and understandable regulations able to capture dynamism the internet creates
- All climate tech projects to account for full, accurate picture of their tech usage and materiality
- Involve de-growth[79] in strategies
- Giving equal access to climate tech and insights to everyone in the world, especially the Global South

4.3 GUIDELINES

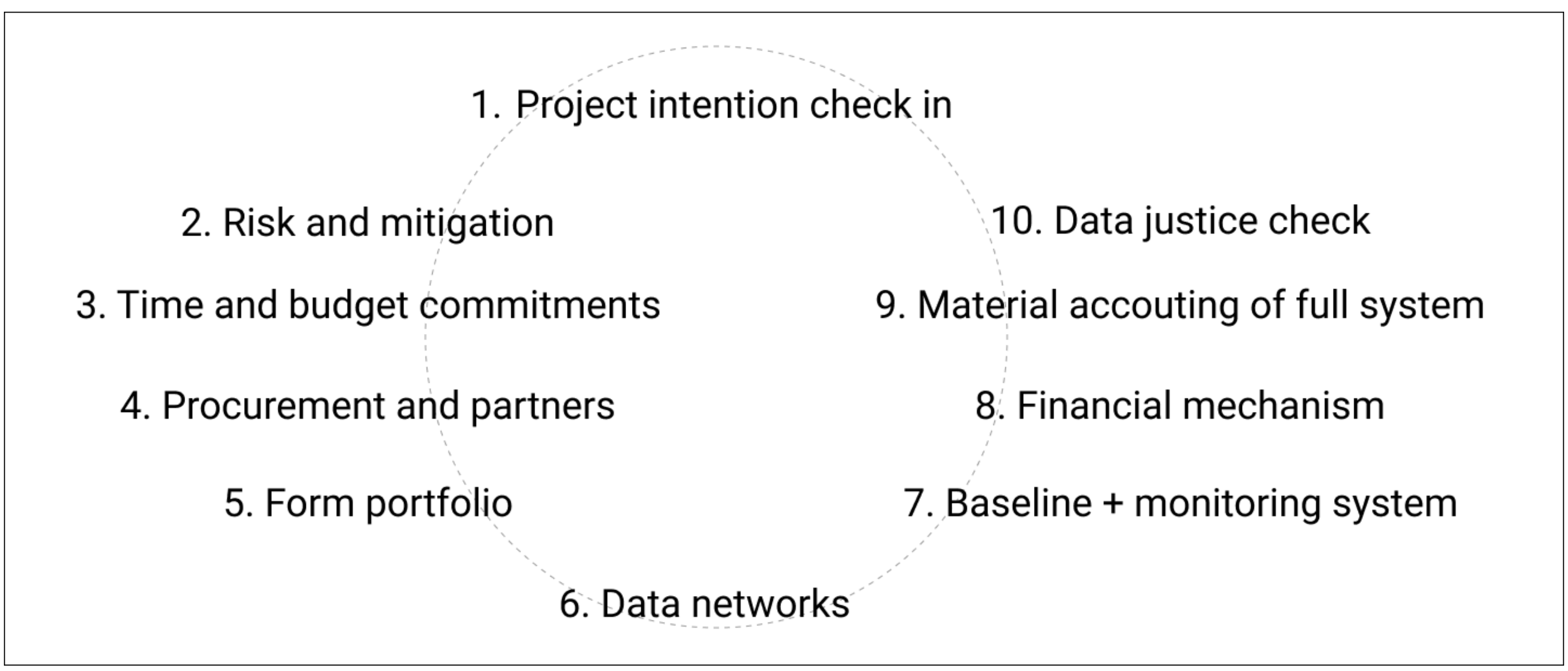


Figure 41 - Guidelines represented as a loop

1. **Project intention check-in**: Understand the intentions of all project stakeholders and participants. Make these intentions transparent and always visible. This visualisation should also show relationships between stakeholders, citizens, and the climate crisis. Work has to be put in to understand contextual landscape but power dynamics affecting the project. And create strategies to mitigate such dynamics and make the project is fairly co-designed. Recognise where there is a need for capacity building and facilitate it. Local citizens, residents, farmers, and caretakers must be made a vital part of the project with decision making,

ownership, and compensation. These intentions need to be updated as the project advances. Followed up with formation of data trusts to create than maintain this.

2. **Black mirror exercise, risk, and mitigation**: Questions such as what could go massively wrong in the long term or with misuse of the climate tech being used in the project, inspired by the TV show Black Mirror. What are short-term and long-term risks, and how would they be mitigated?

3. **Time and budget commitments**: Timelines and budgets need to be stated transparently. Be able to draft everything in easy-to-understand and machine-readable contracts. Set in a way to be able to evolve and change.

4. **Procurements and partners needed, fair process and climate certifications**: Develop process for fair hiring and compensation of all partners required and procurement of people necessary for the context. Fair process and required certification should be established as easy to understand and machine-readable contracts.

5. **Form portfolio**: As stated before, with the entangled nature of the world, a portfolio of the project means mapping out all other projects in place and other activities/people/stakeholders it will also affect. From the portfolio, start connecting with existing projects in the city and worldwide. Share knowledge and form relationships of continuous learning and collaboration.

6. **Data pipelines to data mycorrhizal networks**: Answer key questions about using data in the project. What will data be needed for this project? What insights can it provide? What are measurable parameters, and what are immeasurable? What currently exists in the data pipeline of the city? How to build and sustain such data pipelines? Work on using open licenses and developing existing or novel standards to convert data from closed and fixed channels to open and evolving networks.

7. **Baseline and monitoring mechanism**: Start with understanding what current data exists, if any, create a baseline of the existing value, and find ways to establish baselines of other values. Create hybrid methodologies of data-informed monitoring and impact calculation. Prioritise low-tech monitoring techniques. Validate monitoring and impact methodology with external audit.

8. **Financial mechanism check**: Check how project goals are being financially motivated. Account for fair usage of financial mechanisms in the process and make sure climate action is not being capitalised, i.e., used to generate revenue and that all participants and nature are fairly compensated.

9. **Account of net carbon of hardware, data centre, and other energy+labour**: Be able to account for the realistic embedded carbon cost of using tech and labour around it. Formulate a live update database/material registry to track this.

10. **Data justice and extractive business model check**: Constant check that data justice is in place and the project is not using extractive business models.

There needs to be a long-term place to navigate complexity, foster culture change through local involvement and city council collaboration. Moving forward slowly and iteratively with constant checks and audits of net impact on climate and society.

4.4 LIMITATIONS

The author is not an expert in climate and environmental sciences but collaborates with experts from the field. The projects mentioned are in the early stage and still developing. Some of the topics covered are ideal and can be hard to bring into real projects. Much work is still theoretical and has not been adequately proven in real-world projects yet.

The guidelines still need validation and maturity to be fully used in climate action projects. The guidelines and research cover many different topics together to present a holistic picture of climate tech, but this also means there is a lack of depth and details for some subjects.

4.5 NEXT STEPS

The author will develop both Trees as Infrastructure and Retrofit projects further in the next two years and keep learning from them and sharing insights. Test theoretical concepts in practical settings. Develop all core topics and ideas mentioned further. And evolve guidelines and related topics into a mature and usable toolkit and canvas. At the same time, keeping checking for innovations in climate tech and accounting and updating guidelines.

The guidelines will be validated through qualitative interviews and workshops with climate action professionals and city councils. After validation and needed changes, the guidelines will be published in different usable mediums- website, blog, git-backed code, design canvas, book, and summary poster. Guidelines will be published with Creative Commons open license and go through iterations and improvements. It can be further researched in the author's Ph.D. studies as well.

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FIGURES

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